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Current Problems and Recent News

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The eyes are no more than a minute fraction of the total mass of the human body, but they are instruments of such precision and sensitivity that much of man's progress and mastery of his environment would have been impossible, even inconceivable, without them. We owe much to the pioneers who, in practice and in theory, gradually discovered the nature of the faculty of sight, how to preserve it against failure and fatigue and how to augment its powers. Though the number of scientists, technicians, industrialists and businessmen concerned with optics may be slight compared with those working in other major branches of science, technology, industry and commerce, there are few aspects of present-day life which are not dependent in some degree or another on their skill and service.

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GRAFTING FOR PRODUCTIVITY IN PLANTS AND ANIMALS

by

PIERRE BOITEAU

Pierre Boiteau holds the degrees of Horticultural Engineer and Tropical Agricultural Engineer. In 1934, he founded the Botanical and Zoological Park in Tananarive, where he set up the laboratories of botany, plant chemistry and soil science which were to constitute in 1946, the first sections of the Madagascar Institute of Scientific Research. He was secretary of the recent International Symposium on the Grafting of Vegetable and Animal Tissues, held at the Faculty of Science, Rennes (France).

The term 'grafting' is still associated in the minds of most people with the conscientious arboriculturist who, knife in hand, endeavours to perpetuate the qualities of a tree bearing exceptional fruit by transplanting one of its buds to a less fertile tree. We all know that most of our fruit-trees are hybrids developed by crossing one variety with one or several other varieties and that the qualities obtained in these hybrids are not reproduced in plants grown from their seeds. Furthermore since many of these improved varieties no longer produce fertile seeds, they can only be perpetuated by vegetative reproduction. Thus grafting has come to be regarded as an essentially 'conservative' operation.

This aspect of the matter is not a negligible one. Considerable experience has been acquired in the choice of stocks, grafting techniques and the methods of overcoming incompatibilities between varieties or species, and this experience could be usefully applied in new types of grafting. The quality and yield of tropical fruit-trees, for instance, would be considerably improved if a real effort were made to promote more general use of this purely 'conservative' mode of grafting.

The practice of grafting is of very long standing. We know from the treatises of Pliny the Elder and Columella that it was widely used in ancient Greece and Rome. In the Far East, it was known at least six thousand years before Christ. If we study its long history, we find that, far from being limited to fruit-trees, grafting was even applied to herbaceous plants, in China as well as in Ancient Greece; and, far from being purely 'conservative', it was often employed experimentally in the quest—as old as agriculture itself—for new varieties. Six centuries before Christ, for example, Feng Lu described a crossing between a plum-tree and peach-tree obtained by grafting.

CREATIVE GRAFTING

Although Charles Darwin had already foreseen the creative possibilities of grafting, it was not until the end of the nineteenth century that a scientific study of it was undertaken. The first research on this aspect of grafting was carried out by Lucien Daniel, Professor of Applied Botany at the Faculty of Science at Rennes University. In a paper submitted to the French Academy of Sciences on 30 April 1894, he made the following statement concerning his experiments with the grafting of *Cruciferae*: 'Hybridization by grafting is possible for certain herbaceous plants; we can give them new nutritive qualities by grafting them on plants superior to them in this respect, and by sowing the seeds produced by the graft.'

Up to 1940, he devoted his life to the study of this problem. Although unfamiliar with Daniel's research, the famous Soviet grafter, Ivan Michurin, also endeavoured to obtain new varieties by sexual crossing and grafting. He showed the considerable influence which plants obliged to live in symbiosis exercised on one another, and he concluded that it was possible, by such an association, to improve the qualities of a given variety, particularly its resistance to cold. Likewise in the United States of America another world-famous grafter, Luther Burbank, used, though to a lesser extent, grafting as one of the means of obtaining new varieties.

The work done by these research workers and their followers has made it possible to specify the conditions in which grafting can be creative. Contrary to the procedure followed by arboriculturists, who strip the stock of practically all its leaves, every effort should be made to ensure that the graft will absorb the substances prepared by the stock, by retaining on the latter a large amount of leaf and by stripping the graft of as many leaves as possible. The size of the graft should be reduced in proportion to that of the stock. The respective ages of the two symbions is also of great importance. The plant to be influenced should be as young as possible, whereas the plant whose influence is to be developed should be at a more advanced stage of growth. Experience has also shown that young hybrids—i.e. varieties recently modified by repeated crossings or changes of environment—are more easily influenced than old, very stable varieties, especially wild or relatively uncultivated species. Other methods have also been used to increase the permeability of the graft's cells to the substances emanating from the stock, e.g. wilting or chilling the graft prior to its insertion in the slit. In certain cases, the repeated injection into one plant of sap from another has sufficed to cause considerable variations. Embryonic transplantation has also been used—the embryo of a grain of wheat, for instance, being made to develop on the albumen of a grain of barley or rye previously deprived of its own embryo.

In animals, particularly the higher animals, grafting is attended by greater

difficulties than in the case of plants. Animals are much more independent of their environment. They have developed against external agents a series of reactions known as 'immunity reactions'. When a microbe, for instance, tries to penetrate into the animal organism, the latter reacts by producing specific antibodies which destroy the microbe. The same phenomenon is observed when foreign tissues are artificially introduced into an animal organism, even if they come from animals of the same species. These tissues are attacked by immunity reactions and are usually destroyed or expelled. The intensity of these reactions, however, differs according to the tissues and organs which receive the graft. While the skin reacts very vigorously to every foreign graft, certain regions of the organism (such as the anterior chamber of the eye, the sexual or ductless glands) and the blood, show, subject to precautions which are now well known, a more or less pronounced readiness to receive living cells not only from animals of the same species (homografts), but also from animals of other species (heterografts). It is thanks to these circumstances that the grafting of blood, or blood transfusion, which is now widely practised, has been developed. As early as 1863 the French physiologist Paul Bert, who was also to win fame in other fields, succeeded in effecting the complete union, or parabiosis, of the blood streams of two animals of the same species. Furthermore, as long as they are in an embryonic state, animals show no immunity reactions. It is then possible to implant in them cells from another animal. One this has been effected, they will tolerate later transplantations of tissues from the same donor, despite the fact that their immunity reactions will have then been developed. Lastly, large-scale irradiation, which destroys the cells of the bone-marrow, abolishes the immunity reactions and makes more extensive grafts possible.

Only during recent years has the use of these various methods of overcoming the immunity obstacle made it possible to obtain variations in animals by grafting. Repeated blood transfusions and the parabiosis of embryos during the period of incubation have produced considerable variations in poultry.

Still greater progress has been made in the case of micro-organisms. Even 30 years ago, it was discovered that, by cultivating certain varieties of pneumococci—microbes of pneumonia—with the dead bodies of other varieties of these microbes, the culture acquired new serological properties, characteristic of the previously killed variety incorporated in it. Twelve years ago, it was demonstrated that this variation was due to fact that the living microbe absorbed one of the constituents of its dead congener, namely desoxyribonucleic acid (DNA). Following on this discovery, numerous experiments showed that it was possible to give a microbe fresh properties by making it absorb DNA extracted from another micro-organism. Quite recently Professor Benoît, of the Collège de France, and his collaborators tried out this method on higher animals. By injecting young ducks of the

Pekin breed with DNA extracted from the organs of ducks of the Khaki breed, they obtained a new breed which they called 'Blanche Neige' (Snow-White). These results justify the hope that, during the coming years, these methods will be applied on a much larger scale. Further, it should be noted that hereditary changes have also been obtained in micro-organisms with substances other than DNA: ribonucleic acids, enzymes, activated proteins, etc. These remarks will give some indication of the very considerable prospects now open to experimenters seeking to obtain new varieties with particular characteristics.

SOME ACHIEVEMENTS

Some examples of results obtained by grafting will illustrate the progress made in this domain. Remarkable results have been achieved by research workers in the Institute of Genetics of the Uzbekistan Academy of Sciences, who have succeeded in improving the yield and quality of cotton fibres by grafts between species. In Yugoslavia, grafts between varieties or species have made it possible to develop new varieties of tomato-plants yielding from 40 to 67 metric tons per hectare. A new breed of hen, the Leningrad White, was obtained by repeated transfusions of blood from Australorp hens into Leghorns. This new breed has an average weight of 4,050 grammes, compared with an average of 1,840 grammes for Leghorns, is very robust, disease-resistant and is no longer able to brood, which is a great advantage for market breeding.

Grafting proper, however, offers many other possibilities. It is well known that a common characteristic of sexual hybrids is exceptionally rapid growth, which is called hybrid vigour or heterosis. In the United States of America, this feature has been used in a remarkable way to increase the yield of maize. It has also been used to improve the quality and yield of animals, e.g. by crossing the zebu with the European ox. In sexual hybrids, however, heterosis affects only the first generation—which means that, for plants, the hybrid seeds must be renewed every year; while, for animals, reproduction must be controlled, a matter difficult to arrange in underdeveloped countries where, nevertheless, the use of heterosis would be most desirable. In many instances, grafting also makes it possible to obtain heterosis effects, but in this case the seeds gathered on the graft maintain the hybrid vigour for several generations. Thus, a cucumber-plant increased its yield threefold after being grafted on a gourd; while, as the result of double grafting between a sweet potato and a wild ipomoea, the former increased its yield sixfold. The number of eggs laid by ducks which have undergone embryonic parabiosis is considerably greater. It would therefore obviously be useful to develop these methods.

By associating heterosis of sexual or vegetative origin with grafting on resistant stocks, it is also possible to ensure a substantial increase in the resistance of plants to certain diseases. We have been able, for instance, to increase the resistance of manioc, from which tapioca is obtained, by its grafting—followed by hybridization—with *Manihot Glaziovii,* a species cultivated for the production of rubber.

Grafting can render other extremely valuable services if it is intelligently associated with sexual crossing. First and foremost, it can restore fertility to varieties which have become sterile and thus enable them to be used as a basis for new crossings. A well-known example is the experimental work by which Daniel succeeded in fructifying the Jerusalem artichoke—a species normally sterile in our climates—by grafting it on a sunflower-plant. Similar experiments with sugar-cane or banana-trees, the cultivated varieties of which are sterile, would be of the greatest value.

It is known that the crossing of certain plants is rendered impossible by the incompatibility between the pollen of one of the varieties and the ovary tissues of the other variety; for example, the tomato-plant and the black nightshade, both of which are a wild plants of the *Solanaceae,* cannot be crossed. If, however, both plants are repeatedly grafted together and obliged to live in symbiosis over a period of several years, their incompatibility is overcome and sexual crossings then become possible. Distant hybrids between the pear-tree and the service-tree, between the tomato and the pimento, etc., have been obtained by this method. Likewise, the transplantation of wheat embryos on the albumen of barley has enabled research workers of Lund University (Sweden) to overcome the incompatibility between the two cereals and obtain hybrid seeds from them.

In the U.S.S.R., the grafting of good quality but not very resistant young hybrids on cold-resistant species has made it possible to extend the cultivable area for numerous plants hundreds of miles northwards. The lemon-tree can now be grown as far north as the latitude of Denmark, despite a continental climate with severe winters. The cultivation of the tea-plant, a sub-tropical species, has also been very considerably extended.

The theoretical explanation of the facts we have just described admittedly gives rise to controversial and sometimes very keen discussion. They are interpreted in different and often contradictory ways. The term 'vegetative hybridization', in particular, is regarded by many geneticists as inexact. Such theoretical discussions are necessary, for the light which they throw on different points will facilitate further scientific progress in this field. On the other hand, it would be a costly error to ignore a number of experimental facts and concrete results on the pretext that the theoretical interpretation given to them by their authors was unsound. It is imperative to increase the yield of cultivated plants and of breeding-animals, and to obtain varieties which are more resistant to diseases and better adapted to various climates,

arid soils, etc. To this end, we need all the techniques that experimentation can offer us.

The development of food crops, in particular, is a matter of real urgency in vast regions of the world. Most of these regions are in the tropical zone. For various reasons which we cannot go into here, the attention given to food crops grown for local consumption in these areas, cannot, except in a few rare cases be compared with the detailed and systematic research often done on industrial crops grown for export. The rare improvements in plants such as millet, manioc, the sweet potato and the aroids, which ensure the subsistence of millions of human beings, have been obtained haphazardly. In all the regions of this immense zone (from West Africa, through Madagascar and Indonesia, to the Philippines) in respect of which we possess reliable data, we observe the same phenomenon. If we study the various agrotechnical factors which are influential in increasing crop yields, we observe, in general, that yields can be increased two or threefold by a rational system of manuring, four or fivefold by improved methods of cultivation, and five, six, or sevenfold by rational irrigation; however simply by substituting improved varieties for those at present grown tenfold increases can be obtained.

The conferences held at Dschang (Cameroons) in 1949 and at Fajara (Gambia) in 1952 to study the question of malnutrition in Africa revealed that millions of Africans were suffering from a serious lack of animal proteins in their food, and from the resulting very serious deficiency diseases. It is easy to imagine the great benefit it would be to these countries to have breeds of cattle that were immune from the main epizootic diseases (trypanosomiasis, piroplasmosis, etc.). There are wild species naturally immune from these diseases, and it is not unreasonable to suppose that grafting might make it possible to obtain hybrids from these resistant species and the domestic species.

The foregoing remarks show the great importance, to these countries, of obtaining and selecting new varieties of cultivated plants and more productive breeds of animals, adapted to environmental conditions. The few agronomists and geneticists working in these regions are in a position of particular responsibility, and clearly they cannot refrain, for purely theoretical reasons, from using any of the means offered by science which might help to attain these ends.

The main object of the Rennes symposium on grafting was to place at the disposal of research workers and technicians the available data concerning the results obtained throughout the world by attempts to improve cultivated plants and domestic animals by grafting. At the same time, the symposium paid a well-deserved tribute to Lucien Daniel, one of the pioneers in research work on the creative role of grafting. Because of the rapid pace of present-day research, however, the report drawn up by the symposium is likely to be out of date very soon. For this reason the participants in the symposium

suggested the creation of an international review on grafting, entitled *Daniela*.

We hope that this project—which is by no means an isolated one, since the recent congress at Nice decided upon the foundation of an International Horticultural Society—will effectively help research workers and technicians to solve the complex but fascinating problems involved in developing constantly improved varieties of animals and plants.

THE NEED FOR SELECTORS

Under-feeding and, more frequently, malnutrition—i.e. unbalanced diet, which has serious results—are two of the most urgent problems facing man today. Some tens of millions of children are physically or mentally handicapped, and sometimes condemned to a premature death, owing to the insufficiency, or more generally the unbalanced nature, of their food.

At the Dschang Conference (1949) it was pointed out, for instance, that in the Cameroons the consumption of meat did not exceed an average of 5 kg per person per annum, i.e. 13 gr per day. In the Upper Volta, only 25.2 per cent of the schoolchildren had regular meals. In Chad and Ubangi-Shari, in order to make up for the lack of meat, a large proportion of the rural population took to hunting rats and thus contracted a serious disease —savannah typhus. At Dakar, the blood of only 12 per cent of the inhabitants examined revealed a normal amount of vitamins.

The Fajara Conference (1952) showed that, in Basutoland, the weight of newborn children was much lower than normal owing to the malnutrition of the mothers. In certain centres in Bechuanaland, up to 90 per cent of the children examined were suffering from malnutrition. At Kampala, the capital of Buganda, an examination of the 2,600 children admitted to the hospital showed that *kwashiokor*, a disease due to chronic lack of nitrogen-containing foods, was the main cause of illness and death among children of between one and three years of age. The Gambia report indicated that, during the periods immediately preceding the new harvests, the food value of the rations of maize, which were sometimes replaced by the seeds of wild graminaceous plants, did not exceed 1,000 calories per day, whereas a minimum of 2,800 calories is regarded as necessary.

These brutal facts raise serious problems. It is not always possible to cultivate crops on a more extensive scale; and even if enough land were available for that purpose, the farmers would still have to have sufficient resources to purchase the agricultural equipment now lacking. Here we encounter geographical and economic obstacles that are not easy to overcome.

On the other hand, the immediate employment of rational agricultural methods can lead to a considerable increase in food production. It is difficult to lay down general rules in this matter. Sometimes it is the question of water

supplies, sometimes that of manuring, and sometimes the introduction of new plant varieties that has to be tackled first, depending on local circumstances and the types of crop concerned; but, as we have already seen, the selection of the new plant varieties is a factor that ranks high in importance.

In this respect, one important fact must be emphasized. The mere introduction of improved varieties—the 'easy way out'—is nearly always productive of serious disappointment. The real solution for the problem is to select the new varieties on the spot, in the actual circumstances in which they are to be used.

This is an immense task, which the research stations alone would be unable to carry out owing to their limited working capacities and the fact that they exist in only a few centres.

Thus it is among farmers and breeders in general that future selectors must be recruited. Despite the great difficulty of such an enterprise, we do not consider it impossible. The essential point is to show clearly the importance of such research. To those who might think that very specialized knowledge was necessary for this task, we would point out that the chief qualities of the pioneers in this field were their sound common sense and marked capacity for observation, both of which qualities are to be found in all peoples. Today, moreover, the selector can benefit by the experience of his predecessors; but this experience must be presented to him in a comprehensible form and, above all, efforts must be made to arouse the interest of potential selectors.

There are many types of people who can contribute to this end, whatever their training or vocation may be. Teachers, doctors and politicians can all, in various ways, help to arouse the interest of the rural populations concerned. An important aspect of man's liberation is to learn how to master nature by using its own laws, rather than by using force and destroying irreplaceable wealth. H. G. Wells wrote that 'although, since the days of Buddha and Confucius, there have been very many noble and beautiful things said about freedom, truth and the equal brotherhood of man, the practical liberation of the world mind began not with any of these great aspirations. . . . Invention and discovery are the true liberators'. Could not film-producers or writers find sources of inspiration in the lives of such tireless discoverers as Luther Burbank and Lucien Daniel?

All who co-operate in this task of information and enlightenment will be making a valuable contribution to the solution of one of the most important problems facing mankind.

THE DEVELOPMENT OF OPTICS AND ITS IMPACT ON SOCIETY

by

VASCO RONCHI

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No one nowadays can fail to recognize the fact that science, from its very beginnings, has exercised a powerful and transforming influence on the structure of human society. Everything, for instance, that has helped to make communication easier and faster has immediately brought about far-reaching social changes.

We who see this social evolution gaining daily in momentum are wont to ascribe it to the scientific discoveries and technical inventions of our own times; we tend to imagine that in past centuries the tenor of life was far more even—that scientific progress did not leave so deep an imprint on society as it does today, or even left none at all.

Yet the slightest acquaintance with the history of science is enough to remove this first impression. It shows that, from time immemorial, discoveries have had very marked repercussions on the life of man.

Optics have played a specially interesting part in this development; for this science is a very old one to which mankind owes a great deal.

It goes back over two thousand years; but we can leave aside the first fifteen centuries, during which optics remained the special preserve of philosophers and mathematicians. It was not until the thirteenth century, with the invention of spectacles, that optics began to revolutionize human activity.

The story of this invention is most interesting, though not well known. It did not come about through the rational application of certain scientific laws by a great genius; not only was the invention purely fortuitous, but it was also rejected by scientists—something quite exceptional in the history of science. Viewing the new 'glass lenses' in the light of contemporary optical theories, the scientists were quite unanimous in condemning them. Their verdict remained unaltered for over three centuries.

Lenses might, therefore, never have been heard of again; yet they survived, despite this ostracism on the part of scientists. Since their history will help us to understand other developments in the field of optics, to which reference will be made later, it is worth recounting here.

When lenses were first used, about 1285, for the correction of longsightedness, the law of reflection was already known; but scientists still had only the

haziest notions about refraction, the law of which was not formulated until three and a half centuries later. Without the help of this law, it was quite impossible to understand how a lens worked.

Nor was anything known about the structure of the eye and the operation of its various parts. No one knew why, at a certain stage in life, people with normal eyesight no longer saw as well as in their youth. It was therefore humanly impossible to reason out why a transparent, convex piece of glass placed in front of a long-sighted eye enabled that eye to see nearby objects clearly.

Spectacles were discovered, by pure chance, by a man who used to make oval-shaped pieces of glass in the course of his work. He was probably a master glassmaker who produced the oval pieces of glass which, rimmed with lead, were an ornamental feature of the windows of manor houses at the time. This master must have been fairly old, and he probably looked through these pieces of glass to make sure they were properly made. By noticing that in this way nearby objects appeared as clear and distinct as in his youth, he invented spectacles.

These convex ovals of glass were naturally submitted to the philosophers and mathematicians of the day, but were examined by them with marked hostility. Scientists at that time regarded the sense of sight with considerable mistrust. Its mechanism was not known and everyday experience showed that it was often misleading, making people imagine they saw things which did not exist or which bore little resemblance to the real objects before them. These phenomena were described as *optical illusions*. They led to the logical conclusion that the sense of sight could not be trusted as a means of getting to know the external world, at least without the help of another more reliable sense, such as the sense of touch. All scientists subscribed to the view that *non potest fieri scientia per visum solum* (scientific work requires more than the sense of sight).

It is thus understandable that spectacle lenses should have met with such a cold reception from scientists. Obviously the reality of the imaginary 'figures' seen through the lenses could hardly ever be proved by touching them. Another criticism was levelled against them, one so irrefutable as to meet with general approval: 'The aim of vision is to show us the truth. But the "figures" seen through the lenses are larger or smaller than reality, closer or further away, sometimes upside down and sometimes irridescent. Thus they cannot be real. Therefore we should not look through lenses.'

Small wonder that this was the accepted verdict for three centuries. What is surprising is that, after having been maintained for so long, the objections should not only have lapsed but have been completely forgotten. This is one of the most interesting and least familiar episodes of history, to which I shall revert later. Meanwhile it might be mentioned that, though condemned by the scientific world, spectacle lenses did not disappear completely, but by slow

and painful degrees came to be known all over the world. Simple illiterate craftsmen, ignorant of the philosophers' learned treatises on the nature of truth, introduced to the public these mysterious little gadgets which, placed before the eyes of elderly folk, enabled them to see nearby objects as clearly as in their youth.[1] Once again, it was these anonymous craftsmen who realized how useful it would be to manufacture lenses of different strengths to suit the age of their users. They, too, discovered the 'concave glasses', enabling short-sighted people to see distant objects as well as people with normal eyesight. The concave glasses are nowadays called *diverging or negative lenses,* but at the time such a term would have aroused mirth. Convex glasses for the long-sighted used to be called 'glass lenses', as they had the same shape as large lentil seeds (the word 'glass' being added to distinguish them from the vegetable); but as lentils are never concave in shape, glasses for the short-sighted were not described as 'lenses'.

The very adoption of the term 'lenses' is evidence of the fact that they were first developed and used by craftsmen. When the scientists decided at last to turn their attention to lenses, they disdained so vulgar a word and used the term 'specillum'.

Despite these early difficulties, lenses for spectacles were in time to conquer the world and become indispensable objects. We all know how every person, towards the age of 45 or 50, loses some of his ability to see nearby objects clearly; and this greatly hampers him in his work, especially if it requires good eyesight. We only have to think how a simple pair of glasses enables people to do normal work for the rest of their lives—usually for a few more decades than would otherwise be possible—in order to realize what an extraordinary debt society owes to this invention.

But this is not the whole story. A high percentage of individuals do not enjoy normal eyesight. It is not only at 45 or 50 that they start to be handicapped by failing eyesight; the trouble may begin much earlier, sometimes even in childhood.

Very short-sighted people are a case in point. Anyone with very short sight would be practically paralysed without glasses and capable of hardly any more work than a blind person. If his sight is corrected with glasses, he is nearly always able to do the same work as a person with normal eyesight.

The same applies to people suffering from acute astigmatism or people operated on for a cataract. Without glasses, such people are real invalids; with glasses, they may be said to be restored to normal health.

The cases mentioned above are those of millions of people today. But there is more to tell. Improved methods of eye-testing and the generalization of testing for as many persons as possible, from school age upwards, have

1. One of the first paintings depicting these lenses for long sight is Jan Van Eyck's 'Madonna and Child with St. Donatian, St. George, and Canon George van der Paele' (Bruges Museum), early fifteenth century.

shown that very few people do not suffer from some form of defective vision; most people think that they can see properly only because they do not imagine the possibility of seeing better. If their eyesight is corrected with the high degree of precision attainable today, it can be considerably improved and their capacity for work and output increased, while the fatigue and irritation caused by minor uncorrected defects are greatly reduced.

The wearing of glasses by persons suffering from minor eye defects is already reflected in far higher production figures, and this trend will continue. Expert eye treatment is at present possible only in the most highly industrialized countries, but it will soon spread even to those parts of the world which have made the least technological progress.

In the more advanced countries, a new lens for spectacles is required by about one in every ten people each year, and the number is steadily increasing. A whole group of industries in all parts of the world is working at full capacity to produce optical glass, lenses, frames and many other accessories. A whole army of oculists, optometrists and opticians is engaged in eye-testing and prescribing and providing spectacles for the public.

The extent of this network spreading out from the big industrial centres, with ramifications extending to the smallest towns and villages, clearly demonstrates just how important spectacle lenses have become, particularly in the most advanced countries. Wearers of spectacles (people who at least have a pair in their pocket even if they are not actually wearing them) outnumber non-wearers in these countries. This fact has sometimes made people jump to the rather hasty conclusion that the more frequent use of glasses has resulted in a weakening of the average sight. More thorough study has shown that although it is becoming more common to wear glasses in all countries providing up-to-date eye treatment, this is merely because persistent propaganda convinces the public of the usefulness of eye tests and of the desirability of correcting vision.

The fact is that if our supply of lenses for spectacles were now suddenly to be cut off, the work of the world, particularly in the more advanced countries, would suffer a very serious setback.

Three centuries after lenses were first used to correct long-sightedness, a shattering revolution took place in optical science. A famous mathematician, Franciscus Maurolycus of Messina, was the first to put forward new ideas about the nature of light, the working of the eye, mirrors, prisms and refraction. But he was a pioneer who was not understood and gained no following in his own day. Far greater influence was exerted by Giambattista della Porta, of Naples, whose book on *Magic* was widely read and even translated into the main European languages and into Arabic. It ran to scores of editions, and the author added further material to each new edition. In the 1589 edition, Porta raised the subject of 'glass lenses', though he admitted that no

one could explain how they operated. In 1593, in a work entitled *De Refractione,* he set out to explain the theory of lenses in accordance with the principles of mediaeval optics. Only a man like Porta, with his combination of imagination and illogicality, could have attempted such a task, for the mediaeval theory of optics was totally incompatible with lenses.

Although it was entirely devoid of scientific value, Porta's work was of great importance in that it put an end to the conspiracy of silence which all scientists of the day had maintained on the subject of lenses, and it drew the attention of scientists to the need for a thorough study of these objects that were so useful to mankind.

The effect of his work is quite plain. Under the modest title *Paralipomena ad Vitelliomen,* Johannes Kepler published in 1604 a remarkable book in which, working on the theories of Maurolycus and Porta, he first explained the mechanism of vision as it is understood today. This was the culmination of research which had engaged the attention of mathematicians and philosophers for at least two thousand years.

This work by Kepler marked the advent of a new optical science, which can be described as 'seventeenth century optics' and is, to all intents and purposes, that existing today.

Kepler's work at first produced little effect. It was neither understood nor appreciated. To bring about a change in ideas, this technical revolution was not enough; a philosophical revolution was also needed, since the sceptical attitude of learned circles towards the sense of sight and optical instruments still had to be broken down.

This second revolution soon followed in the wake of Kepler's work.

From the documentary evidence available to us, it appears that in 1590 an Italian craftsman, making glasses for the correction of vision, built the first telescope with a diverging eye-piece and, naturally enough, used the same lenses as he did for his spectacles. This new piece of apparatus also met with a cold reception from scientists; all who saw it declared unanimously: 'Do not look through the telescope, for it is a deceptive instrument; it does not show the truth.'

This time, however, the ostracism did not last for centuries. In 1604, Dutch craftsmen reproduced the Italian model of 1590, and before long other craftsmen took up the production of this new type of glass which made distant objects appear as clear and distinct as if they were close at hand. They too had to put up with misunderstanding and indifference. It must be admitted that these telescopes, made with lenses for correcting vision, were really of poor quality. The blurred, irridescent 'figures' seen through them doubtless appeared larger than to the naked eye, but they were no more detailed. These telescopes never magnified more than three diameters; beyond that limit the images would have been so blurred as to be completely useless.

The general indifference shown towards the new instrument is therefore

understandable. Scientists and philosophers regarded it with preconceived hostility; but it was the instrument's technical shortcomings which prejudiced it in the eyes of the general public. The reason why lenses for correcting eyesight had survived centuries of condemnation on the part of scientists, was that they had proved effective and very useful in practice. But this poor type of telescope made by spectacle-makers, which had no practical success to recommend it, would have been lost for ever, had it not had the good fortune to arouse the interest of Galileo.

In the spring of 1609, Galileo, then Professor of Mathematics at the University of Padua, heard of the existence of this telescope. He built one himself, even grinding the lenses with his own hands. In so doing he discovered two most important facts:

1. A telescope with a certain magnifying power may be of good or poor quality, depending on the way in which the lenses have been ground; lenses for correcting vision always make poor telescopes, and the production of a good instrument required the use of a different raw material and the grinding of the lenses in a different way.
2. A good telescope could have a magnifying power of more than three diameters, in which case it became *uno strumento di giovamento inestimable* (an instrument of inestimable value). These were the words used by Galileo in a letter addressed to the Doge of Venice on 24 August 1609. They ushered in a new scientific age, the age of faith in observation with the human eye and with optical instruments, which was to supersede mediaeval scepticism. This revolution is one of the basic factors in the tremendous scientific progress made over the past three centuries. A few instances will be given in the following pages.

It may be wondered why Galileo's attitude towards the telescope was so different from that of all the scientists of his day. Two things may account for it. The first is Galileo's character; he was a positive, observant man who preferred to read 'the book of nature' rather than the books of his masters. The second is his complete ignorance of optics. He had never made a study of the subject, so that he was able to approach the telescope with a completely open mind. Under the circumstances, both these factors were greatly in his favour.

Furthermore, with all the zeal of the inventor, he set about improving the technical quality of the telescope and eventually produced instruments that magnified up to 30 or even more diameters. These are the instruments known as 'the Galilean telescopes'. Although their basic design was the same as those of the ordinary craftsmen, Galileo's telescopes had far greater precision and power.

The general public had only a very hazy idea of the change that had taken place, and the poor craftsmen's telescopes were soon completely overshadowed by the Galilean telescope.

Yet there was one man who because of his thorough knowledge of optics, was able to understand and explain the difference between the two types of telescope. This man was Kepler. In a justly famous letter, he described the craftsmen's telescope as a 'tube with two lenses', and the Galilean telescope as 'an instrument which has opened up the heavens'.

For it was with his very powerful telescope magnifying 30 diameters (quite remarkable for that time) that Galileo, within a very short period, made his great astronomical discoveries—the hills and valleys on the moon, the phases of Venus, the stars making up the Milky Way, the spots on the sun and, above all, the four satellites of Jupiter. These discoveries completely revolutionized the astronomy (and, what is more extraordinary, all the medical science) of the day.

The repercussions of Galileo's discoveries on the seventeenth century scientific world are not well known today. As soon as they were published in his marvellous little book *Sidereus Nuncius,* the first copies of which were put into circulation on 10 March 1610, a general storm of protest and even calumny broke upon the author.

A bitter controversy ensued between Galileo and all the scholars of his day. Kepler was the first to admit the justice of Galileo's cause—but not until some months had elapsed. In September 1610, Kepler wrote his *Dioptrice,* another marvellous little work, in which he first expounded the theory of lenses and the telescope. Kepler developed this theory from the new ideas he had set forth in 1604 in the *Paralipomena ad Vitellionem.* The new seventeenth-century science of optics was beginning to bear fruit.

It took a long time for these new ideas to gain acceptance in scientific circles; yet such acceptance was inevitable. What was involved was a question of faith rather than reason, and it was only among young people that these ideas awakened any sympathy.

The new science of optics was born and was destined to conquer the world; this science gave the name 'lenses' to concave and convex pieces of glass alike, and regarded light as consisting of rectilinear rays pointing in all directions.

After the brilliant victory of the Galilean telescope, the technique of optics developed along two different lines. On the one hand, craftsmen continued to make spectacle lenses to correct eyesight, using the same raw material and methods as in preceding centuries. But at the same time there emerged a new technique, using a special glass known as 'optical glass', of very great purity and homogeneity. By grinding this optical glass with a very high degree of precision, it was possible to make more and more powerful lenses, and the way thus lay open for great increases in the production of optical instruments.

The social repercussions of the extension of this new technique are incalculable. We have only to consider how much of the scientific and technological progress of the past two centuries is due to the fact that scientists

had at their disposal the increasingly accurate and powerful means of investigation, made available by the development of precision optics.

In the last analysis it may be said that the sense of sight is the most powerful (if indeed it is not the most reliable) instrument used in scientific research. While spectacle lenses to correct eyesight had the great merit of restoring normal vision to many people with eye defects, they did not give people with normal eyesight any greater powers of investigation. This was the special prerogative of optical instruments such as the telescope or microscope which enabled people to 'see' (i.e. extend the field of research carried out by ocular means) for distances, or in detail, quite beyond the range of the naked eye. This increased power could not but have far-reaching repercussions on human life and activity. We can now consider some of the most striking social consequences of these developments.

As Kepler so aptly remarked, the Galilean telescope had 'opened up the heavens'. The Ptolemaean system fell to pieces under the weight of the observations and measurements made with the telescope, once people began to 'believe' blindly in what could be seen with it. (This may appear to be a play on words, yet it accurately reflects the attitude of the day.)

The Earth, previously considered as the centre of the universe, lost its privileged position as did the 'heavens' studded with planets and stars which were supposed to revolve about it for the delectation of its inhabitants. It became a humble servant destined to revolve about its master, the Sun.

The sun, in turn, was regarded for some centuries as the centre of the universe. But before long it too was dethroned, to become a very insignificant star lost among the millions of similar stars which were drawn by an invisible force, into a movement of rotation around the centre of the Galaxy. The discovery of countless other nebulae, scattered throughout space at distances of millions of light-years, reduced the importance of the Earth in the universe to still more humble proportions.

Nowadays it is nothing more than a tiny planet revolving around a small sun which in its turn revolves, with many other stars, in numerous galaxies of the universe. The Galilean telescope did, indeed, open up the heavens.

This revolution did not remain confined to the astronomical observatories. It brought about radical changes in the basic conception of life, and particularly in the main tenets of religious systems. Previous ideas regarding the important place occupied by the human race in the universe obviously had to be revised; but it was not easy to accommodate classical religious views of humanity as dominating the globe at the centre of the universe to the conception of human race as the inhabitants of an insignificant little planet lost in the vastness of space.

These considerations concern the realm of philosophy; but optical instruments such as the telescope have also had a considerable impact on everyday life. We need only think how essential they are to the powerful weapons

which have decided the outcome of battles in this century. Long-range artillery cannot operate without aiming instruments and telemeters, and the submarine cannot do without periscopes. All these instruments derive from the telescope.[1]

Nowadays the optical industry, which produces instruments for military purposes, is regarded as a key industry, for on it depends the effectiveness of the armed forces.

No less interesting has been the development of optical instruments such as the microscope. Little is known about their history, as attention is now concentrated mainly on what is known as the *compound microscope*. But this type of microscope has been used on a large scale only for about a century, whereas all the great discoveries of the seventeenth and eighteenth centuries in the field of microscopy were made with the *simple microscope* (magnifier). Van Leeuwenhoek himself, who is regarded as the father of microscopy, used only simple microscopes.

The simple microscope consists of a simple converging lens. In fact, even an ordinary concave mirror can be used as a microscope. Why then, it might be asked, was microscopy not taken up until the second half of the seventeenth century? Since a concave mirror can be used as a microscope and such mirrors are discussed as early as the fourth century B.C. in Euclid's *Catoptrics*, surely microscopy could have dated from that period.

And since a converging lens is the main feature of the simple microscope, why did it not begin to be used for that purpose at the end of the thirteenth century, when converging lenses were employed for the correction of long-sightedness?

It is surprising to note that in 1523, the Florentine Giovanni Rucellai published a poem describing the microscopy of the bee, which he had observed with the aid of a concave mirror.

It was not, therefore, because no one had had the idea of applying existing optical aids to microscopic observation that microscopy was taken up at so late a stage. There must have been some other deeper reason.

The clue to this enigma can be found in the sceptical attitude, which, as we have seen, dominated the philosophy of Antiquity and the Middle Ages, towards the heuristic value of the sense of sight.

Those who held this attitude were bound to regard with extreme suspicion the description of a bee observed by means of a concave mirror; they were careful not to encourage such observations or to extend them to other objects, since, in their view, they were completely worthless. No other sense, more particularly the sense of touch, could provide any confirmation whatever regarding the reality of what could be seen with the optical devices used for

1. As early as the seventeenth century, the first field-glasses were of tremendous assistance to the Dutch in their struggle against the Spaniards for national independence.

microscopic observations. This philosopher's scepticism as to the value of observations made with the eye and with optical instruments was one of the greatest mistakes in the history of science. It cost mankind two thousand years of microscopy.

To have some idea of what these two thousand years could have meant we need only give a moment's thought to what mankind has gained from microscopy in the three centuries since Van Leeuwenhoek made the first of the endless series of discoveries that have enriched the sciences of biology and histology. Van Leeuwenhoek must not be regarded as a scientist; the fact that he was a practically illiterate usher in the States-General, whose lack of education handicapped him in giving accurate descriptions of the discoveries he made with his tiny instruments bears out what we have said regarding the scepticism of the philosophical world. Although, after the Galilean revolution brought about by the development of the telescope, scientists no longer dared to express open hostility, they still showed no enthusiasm or initiative in using the new research facilities opened up by lenses. Further progress had to come from ignorant outsiders whose minds had not been contaminated and paralysed by philosophical prejudices. They were able to bring to their research the true faith of pioneers, convinced as they were that exploration would yield rich rewards.

The fact is that not only biology and physiology, but also anatomy, histology and indeed all medical science, have made enormous progress since they opened the door to the microscope. When the compound microscope, which came into common use a little over a century ago, had reached the limit of its possibilities, the electronic microscope appeared and carried the field of investigation beyond the reach of the optical microscope, to areas which had once seemed completely closed to research.

The most direct impact of the microscope on society has been in the field of therapy; but it has also played a very important role in industrial production, particularly in the engineering and chemical industries—two branches of industry which have contributed outstandingly to the transformation of society in the past century. Indeed, these industries made the greatest strides once they were able to produce goods characterized by extreme precision, and the microscope has obviously been one of the basic factors in this development.

The microscope has not been alone among optical instruments to exercise an indirect influence on twentieth-century mechanization; a whole host of instruments, differing widely in form and function have also had their effect. No scientific laboratory today is without at least one instrument fitted with a vital set of lenses. It is thus no exaggeration to claim that if optical instruments were to disappear entirely, civilization would suffer a tremendous loss.

So far I have dwelt only on 'typical' optical instruments. But if the term

'optics' is used in a broader sense, it will be found to cover many other fields of great social importance.

It is customary to regard optics as the science which studies 'light and luminous phenomena'; it should therefore include the 'production of light'. Moreover, 'light' is now generally taken to mean not only 'the light that can be seen', as understood by the man in the street, but also the physical agent (consisting of electromagnetic waves or photons) which is usually, though not always, capable of making an impression on the human eye.

In practice, however, the production of light is not regarded as falling within the domain of optics. When we have to do with flames, we enter the sphere of industrial chemistry; and a discussion of incandescent filaments or electric discharges in rarified gases would carry us into the field of electrotechnical applications.

This *de facto* division is far more rational than might be imagined. The habit of taking the word 'light' to mean both what can be seen and the physical agent capable of producing the sense-impression is philosophically erroneous, and even dangerous in practice. Indeed, the 'seeing' of light is a psychic type of phenomenon; whereas the external agent is clearly of a purely physical character. The use of the same term to denote these two things is a source of great complication for specialists, who are forced to specify in each case which concept is implied. It is also responsible for gross misconceptions on the part of non-specialists, who are led to believe, quite wrongly, that both concepts mean one and the same thing.

This confusion leads to absurd contradictions, and it is extraordinary that scientists and technicians have not drawn attention to them earlier. It is particularly marked in photometry, which claims to 'measure light', whereas in fact it measures only one conventional function of the physical agent. The confusion grows even worse when we come to the technique of lighting, which aims to enable people to 'see clearly' by manipulating the external agent.

These ideas are becoming clearer today; yet the process is very slow, for the practice of referring to the external agent as 'light' is age-old, and deeply rooted in the positivism prevailing even in the recent past. But specialists are now giving the external agent the name of 'radiation', and keeping the word 'light' for what can be seen. The main concern of optics is thus to explain how radiation produces light.

It is now understandable why the 'production' of radiation had been regarded as a branch not of optical science, but of chemistry or electrotechnology. However, since optics definitely enters into the 'utilization' or radiation for the production of light, we feel justified in dwelling on this aspect.

Here, again, the impact on society has been very great. Not only do sources of intense, visible, convenient and inexpensive radiations considerably improve physical, physiological and psychological well-being, but artificial lighting has also had a tremendous influence on industrial output and human

activity in general. We have only to think how all branches of activity are paralysed when light is cut off through some technical breakdown.[1]

To use the phraseology of the modern theory of mass communication, the function of the human organ of sight is to transmit to the psyche the fullest possible information concerning the outside world, so that this can be turned to account for all the demands of life. No other sense yields so rich a harvest of information as the organ of sight.

The nature of this harvest of information is obviously related to the useful energy absorbed through the eyes. The mere fact of having, in addition to the energy derived from the sun, the enormous amount of energy now provided by visible radiation in artificial lighting, has greatly enriched the spiritual life of mankind and quickened its tempo.

The great importance of this new source of light prompted inventors to seek retinas other than the eye, capable of registering information other than that received directly by the eyes. The first of these new forms of 'retina' was the *photographic plate*.

It is worth mentioning that this very important type of 'retina' was perfected as a result of the perseverance of many imaginative amateurs, without any effective contribution from scientific research workers. It may be claimed that the photographic process was worked out entirely by trial and error. Its success was largely dependent on the fact that two entirely independent lines of activity happened to converge.

On the one hand, landscape painters had the idea of using the *camera obscura* to obtain a faithful and geometrically accurate image of the subject they wished to depict. With the aid of the *camera obscura,* the painting of a landscape was reduced to the copying of the actual image projected by a lens on the focusing screen.

On the other hand, many chemists had discovered that silver nitrate turned black when acted upon by sunlight; other substances were discovered which underwent various types of change when exposed to radiation. Niepce, a retired colonel, applied these properties in interesting ways to lithography. A few people became intensely interested in these phenomena, and conceived the idea of using these chemical properties for the direct recording of the real images projected on the focusing screen by the *camera obscura* lens. They planned to replace the focusing screen by a plate coated with a layer of some light-sensitive substance.

Early attempts, using known substances, were encouraging; but there were two serious disadvantages. To begin with, in order to obtain satisfactory results, the plate had to be exposed to direct sunlight for a whole day. Moreover, even though it was possible, after so lengthy an exposure, to obtain on a plate coated with silver nitrate, for instance, dark areas alternat-

1. We should also note here how much society owes to the mediaeval invention of sheet glass which made it possible for people to use natural light in their houses.

ing with light areas (as in a modern photograph), the whole of the sensitive layer inevitably turned black when acted upon by the diffused light in the surrounding atmosphere.

The latter difficulty was soon overcome by the invention of the 'fixing process', whereby a solution of sodium chloride (today replaced by sodium thiosulphate) was used to dissolve away the silver salt not decomposed by exposure to light. But the discovery which really set photography on its feet, and led to its wide dissemination, was the 'latent image' produced by Daguerre in 1839—in co-operation with Niepce—after many years of trial and error. Daguerre, who was a scene-painter at the Paris Opera, was rewarded after years of unsuccessful experimenting without theoretical guidance, by the discovery of this strange phenomenon, which remained unexplained for over a century. The key to the mystery was recently provided by atomic physics, the explanation being far from simple.

The phenomenon of the latent image consists in the subtle change undergone by the atoms of certain substances when exposed to light for even a short period. As a result of this change, these substances may be attacked by certain oxidizing or 'developing' agents which produce the dark part of the image.

After Daguerre's discovery, the exposure necessary to obtain a photograph was reduced from one day to a few minutes; and subsequent increases in the power of camera lenses, combined with the discovery of silver salts more sensitive than those used by Daguerre, have reduced exposure times to a few thousandths of a second.

Photography has had tremendous social consequences. It is responsible for the birth and development of the cinema, for one thing. There is no denying that the *image,* whether still or in motion, is a means of communication between men of all races and all languages, far more universal than the spoken or written word which comes up against the insurmountable barriers of language. The advocates of the 'image' define it as a universal language—which may be going a little too far. However that may be, the photographic or cinematographic image, regarded as a 'storehouse of information', affords a means of communication by optical means which make a far more intense impact than is possible by oral means or the printed word.

There is no need to stress the social importance of films and photography in general as a means of spreading culture and helping peoples to get to know one another. Alongside these visual media we must now place television, which relies on a third means of making radiation visible—the *photoelectric cell.*

We have now reached the stage when it is necessary to apply new criteria to the study of optical science.

Until the early nineteenth century, scientists knew only about visible radiations, and for them the only means of recording such radiations was

the eye. The effect of visible radiations on the eye resulted in a psychic representation of *light* and *colour*.

Early in the nineteenth century, the existence of invisible radiations which make no impression on the human eye was discovered. They were detected by means of thermometers and as a result of their actinic properties. These radiations were called 'infra-red' and 'ultra-violet', and it was thought natural to study them as part of optical science, as they behaved in much the same way as visible radiations. As the radiation studied in optics was termed 'light' and 'colour', these new radiations which make no impression on the eye came to be called 'invisible light' or 'black light'.

After the invention of photography, which revealed both visible and invisible radiation and used lenses which were regarded as optical instruments, this subject was included in optical science. Early in the twentieth century, photoelectric cells also revealed visible and invisible radiation and they, too, were incorporated in optical science.

But it was finally realized what an exaggeration it was to extend the word 'optics' to include such varying phenomena, many of which were really quite unrelated to optical science.

The photoelectric effect, for instance, may be summed up as follows. Electromagnetic waves are emitted from some source; as they traverse certain convex pieces of glass, these waves are concentrated on a cell connected with an electric circuit, which thus sets up an electric current in this circuit. This process has nothing to do with optics.

The photographic process may, in turn, be briefly described in the following way. Electromagnetic waves given off by an object traverse convex pieces of glass which focus them on a layer of silver salts in which they set up certain electronic reactions. After chemical treatment in the form of development and fixing, a metallic silver deposit is obtained. This process, which is known as *darkening*, has nothing to do with optics either. As our intention was to deal with the impact on society of progress in optics, we shall leave the questions of photography and photoelectricity at this point.

The eyes are no more than a minute fraction of the total mass of the human body, but they are instruments of such precision and sensitivity that much of man's progress and mastery of his environment would have been impossible, even inconceivable, without them. We owe much to the pioneers, who, in practice and in theory, gradually discovered the nature of the faculty of sight, how to preserve it against failure and fatigue and how to augment its powers. Though the number of scientists, technicians, industrialists and businessmen concerned with optics may be slight compared with those working in other major branches of science, technology, industry and commerce, there are few aspects of present-day life which are not dependent in some degree or another on their skill and service.

TEACHING THE HISTORY OF SCIENCE

by
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The question of adding the history of science and technology to the university curriculum has been brought up from time to time since the end of the last century; but in recent years it has become much more pressing. It has been realized in many quarters that in view of the great and steadily growing part played by scientific and technological progress in human existence, people today ought at least to have some summary knowledge of the way in which the sciences and technology have developed and influenced other factors in the history of civilization.

Although efforts in this direction have been made in different countries, the solutions adopted do not, in most cases, seem really satisfactory or fully adequate. So important a problem deserves fresh study. After noting the compelling arguments in favour of more extensive instruction in the history of science and technology, we shall consider some examples of what has actually been attempted along these lines. The various goals to be reached and the main difficulties of organization to be overcome will then be described; a few suggestions will result, and these may help towards what would seem the most satisfactory solution of the problem.

At the beginning of the nineteenth century, it was still possible for an ill-informed person to maintain, with some plausibility, that the course of scientific and technological progress was only of somewhat indirect concern to him. At first sight, the daily life of a man of humble rank seemed to differ little from that of his remote ancestors. In reality, however, many aspects of life had already been influenced by technological progress, and its effects on the community as a whole were even more far-reaching. Moreover, the beginnings of modern science in the seventeenth century had profoundly altered man's concept of the world. He no longer believed himself to stand at the centre of the universe; he lived on a planet of the solar system, whose movements could be explained rationally and in detail by the law of gravitation. Thanks to progress in mathematics and the experimental method, each new day brought the explanation for some pheno-

menon of the physical world; the advance of science even offered a glimpse into the mechanism of much more complex phenomena related to the activity of living organisms. The applications of science were soon to have a decisive effect; the perfection of the steam-engine and the invention of the battery were signs of vast changes shortly to occur in the life of humanity.

Now, 150 years later, as this second half of the twentieth century gets under way, scientific and technological progress is wielding such an influence over our daily existence and every aspect of society that even the most ignorant person is struck by it. Mechanization, electrotechnics and electronics have been put to uses which have completely transformed living conditions; the advances made in the release of atomic energy arouse immense hopes and sometimes well-founded fears. At the same time the revolutions that have taken place in most fields of pure science since the beginning of the century have also made their impression on the general public. Not only do these revolutionary developments affect every detail of our daily life, but they also modify every aspect of community existence, and the history of the modern world is becoming more and more inseparable from the history of scientific progress and its technological applications. As a result, laboratories of pure and applied research in all countries of the world are developing rapidly and so speeding up progress even more. A direct consequence of this process is that most States are working out reforms in education to ensure that young people will be better prepared for the life of tomorrow, which will be characterized by increasingly complex technology.

At the end of the eighteenth century the French Revolution had introduced sweeping changes in education, which, as they were gradually adopted by the majority of countries, powerfully contributed to the rapid advance of science and industry during the nineteenth century. Far more attention was paid to scientific and technical instruction, at the expense of theology, rhetoric, philosophy and the ancient languages which had had pride of place in an eighteenth-century gentleman's education. Today we have reached an even more significant turning point, and equally bold reforms are being planned or carried out. This new transformation in our teaching methods is made inevitable by rapid technological development, but it is far from being without perils for the future of humanity. We may wonder whether the growing importance of scientific and technological education, and the specialization at an early age required by the inordinate demands of scientific instruction, may not be tolling the knell of disinterested culture and humanism. Is it not to be feared that, sooner or later, the life of our planet will be under the sole direction of dehumanized technicians concerned only with material advantages, the excesses of which will not be tempered by a cultivation of the mind?

If this very grave danger is to be avoided, a classical education based on literary and artistic culture and humanism must be maintained, at least for a minority, differing only from the type we know in that it should give greater importance to the social, economic and human sciences and offer a fuller introduction to the scientific and technological aspects of our civilization. For most people, however, a predominantly scientific or technical culture must, without any doubt, replace traditional education. Its attendant specialization, which must be embarked upon at an early stage, can only take place at the expense of some part of classical culture. Not only will the teaching of the humanities be restricted, but the general scientific instruction given will also often have to remain fairly rudimentary since most of the teaching will have to be directed early to certain particular fields, in order to speed up the training of research workers and technicians. Such a policy is already followed by many institutions in the more advanced countries, and it will almost inevitably spread to others, since rivalries between nations are increasingly assuming the aspect of races between their laboratories and centres of applied research.

Two contrasting risks are involved in the organization of these two types of education centred respectively around the human and social sciences and the pure and applied sciences.

In the first case, those whose education will include only limited scientific training must not be made to feel at a loss in a modern world swamped by technology and science, of which only a distorted idea can be gained from the traditional sources of information. Some instruction in the general history of science and technology can be a salutary means of countering this danger. The main object of this instruction, of course, will not be to impart any kind of academic erudition, but to show that scientific and technological progress has been a determining factor in all transformations of the human mind and of the material life of society, inasmuch as it has enabled man to discover the secrets of nature and to use the resources of the universe to his own advantage. It will also show that the rapid acceleration of this progress means that those societies whose power is thus being constantly expended will have to bear correspondingly greater responsibilities. It must, if it is properly conceived, emphasize both the inspiring character of the scientific adventure and the need to supervise man's use of the immense forces now being placed in his hands. This type of education will enable students to understand the deeper meaning rather than the technical details of the trend towards a world in which science and technology will give man an even greater mastery of the material universe, and will impress upon them the responsibility they must accept of maintaining human values, 'humanizing' science and ensuring that technology will serve the interests of man.

Steadily increasing numbers of young people begin scientific and technical

training early in their school careers. There is a possible danger that such precocious specialized training might leave them deeply in error as to the true nature of human values and ignorant of the other aspects of the cultural and social life of mankind. In order to avoid this danger, it seems possible to offset, at least partially, the lack of general culture on the part of future scientists and technicians by introducing the general history of science and technology into their educational programme. Courses in this subject should aim at giving future research-workers and technicians an idea of the major phases of human history and civilization; they should be enabled to appreciate the part played by scientific and technological development in the evolution of humanity, and to realize how, at different times, such progress has taken place in harmony with other human activities. This historical 'briefing' should concentrate more on methodological, cultural and social considerations than on technical details. If it is thus approached from the angle of the relations between scientific progress, the evolution of civilization and cultural, economic and social life, it will acquire real humanistic value. Young scientists will realize that their profession of tomorrow, however absorbing it may be, must not force them to neglect the other human values, and that an unduly narrow and exclusive technical outlook may distort their judgement in regard to the great problems with which mankind will continue to be faced.

Thus, at a time when administrators in all countries are endeavouring to devise and perfect new forms of teaching to prepare young people for the propects which scientific and technological progress is opening up to humanity, the institution of instruction in the history of science and technology would appear highly desirable. Presented in varying forms, according to the specialities of the students for whom it is intended, it should occupy a central place in the humanistic training of the new generation.

We shall now consider the subject in relation to secondary education, then a few actual examples of the teaching of the history of science at university level, before going on to suggest, tentatively, some principles which may serve as a guide in the adoption of the most suitable and effective teaching approach in each case.

SECONDARY EDUCATION

The arguments in favour of more extensive instruction in the history of science are particularly applicable at secondary school level, where the main object must be to prepare young people for adult life in twentieth-century society. These pupils cannot, of course, be taught the whole history of science and technology. The curriculum is already too full to accommodate any additions to its bulk. The change should merely be a matter

of giving a few fresh 'slants' to the traditional teaching of science and history.

The teaching of science must, so far as possible, avoid the formal, didactic presentation of a sum of scientific achievement; it should rather stress the principles of the scientific method and the complex, varied mechanism of research and discovery. In France during the past few years, under the guidance of Mr. C. Brunold, a special effort has been made in this direction, using the very fruitful teaching method of what is termed 'rediscovery'. The idea behind this method is to present science, not as a completed edifice, but as a building undergoing continual improvement; the pupil is made to appreciate science's 'hesitations and sudden advances, successes and failures'. Such a system has the advantage of showing the increasing speed at which discoveries and inventions are taking place, and the need for modern man to retain a degree of mental flexibility so that he can adapt himself easily to the technological revolutions he is bound encounter in his lifetime. This treatment of science as a constantly developing process will, for the most advanced pupils, be supplemented by a few lessons on the history of the principal theories concerning the major branches of physics, the composition of light, the system of the world, etc. Obviously the approach must not be in any way academic or erudite, and attention should be concentrated only on the main line of development and the essential stages in the history of the great theories. Full importance must be given to the way in which certain revolutionary developments in science have enriched and increased the powers of the mind. Stress might thus be laid on the fundamental conceptual changes introduced by the Copernican revolution, the development of the doctrine of transformism, the revelation of the atomic structure of matter or the physico-chemical mechanisms of life, the release of atomic energy, etc.

History teaching can also help to make these things clear; but instead of the 'vertical' exegesis of the science teacher who follows the evolution of one theory, it would resort to 'horizontal' descriptions reconstructing the life of science at different periods. Scientific and technological history will not be studied in isolation, but placed within its political, economic and social context. The emphasis will be on the major technological transformations, their causes, the ways in which they were brought about, and their economic and social consequences. In this new light, the general march of history will be better understood, and the contributions of the major civilizations to human progress more fully appreciated. For example, the grandeur of Chinese civilization cannot rightly be appreciated unless the high level attained by Far Eastern science in certain fields is realized, and especially the importance of China's contribution to technology. So, also, due recognition must be given to the eminent place occupied by science in the Moslem world, especially from the ninth to the twelfth century. While

the scientific revolution of the seventeenth century should be clearly illustrated, the increasingly obvious role played in human life by science and technology since the end of the eighteenth century must be given particular emphasis. The now marked speeding-up of the rate of progress is a phenomenon of the highest significance, and pupils must come to realize that the fate of mankind depends essentially on the success with which this constant progress can be assimilated and used for human betterment. The increasingly international character of scientific and technological development shows that the problem transcends national frontiers and that, while technology and pure science are exerting a more and more direct influence on our daily lives, it is really at the world level that their essential impact is being felt. By bringing out these various points, history teaching will attain its fundamental objective, which is to use the knowledge of the past in training young people for their task of building the future of mankind.

These few suggestions concerning the advantages of introducing a general idea of the history of science into science and history teaching in secondary schools should not involve any thorough-going revision of the curriculum. They merely call for a new approach to the presentation of scientific questions and for closer attention by history teachers to the influence of science and technology upon human life within the great civilizations. They will create no problems for the pupils, who have, since childhood, come to realize the growing role of technology and the scientific progress on which it is based. A fairly considerable effort will be demanded of the teachers, but they could be helped a great deal by the introduction of new textbooks specially written for this type of teaching. A more extensive use of audio-visual aids could also greatly facilitate their work. But final success in this reform in teaching methods will be achieved only when corresponding reforms are adopted in teacher training. A study of the most effective means of introducing the teaching of the history of science in the universities will make it possible to define this last problem and envisage the necessary solutions.

THE PRESENT PLACE OF THE HISTORY OF SCIENCE IN HIGHER EDUCATION

In order to reach a clearer assessment of the prospects for the university teaching of the history of science, it would appear useful to study a few achievements, and even certain failures, in this sphere. We shall make some general observations, without however attempting to give an appraisal of all the present teaching patterns; a survey carried out for this purpose some years ago by Professor E. J. Dijksterhuis[1] yielded rather disappointing

1. E. J. Dijksterhuis, 'La place de l'histoire des sciences dans l'instruction supérieure,' *Arch. Int. d'Hist. des Sci.*, t. 3, 1950, p. 39-76.

results, since many of the answers received lacked precision and objectivity.

The first professorship in the general history of science was that founded at the Collège de France in Paris in 1892, at the prompting of various disciples of Auguste Comte. Its rather unfortunate history is worth recalling, because it illustrates some of the difficulties encountered in the organization of such teaching. This professorship, then the only one of its kind in the world, was first entrusted to a representative of the Positivist school, Pierre Laffitte, the rather weak quality of whose teaching did not fulfil the hopes placed in the enterprise. At the time of Laffitte's death in 1903, France possessed a first-class historian of the sciences, Paul Tannery, and there was thus an opportunity of giving fresh lustre to the professorship in question. But Tannery's candidature was ruled out, for political reasons, in favour of that of a crystallographer, Grégoire Wyrouboff, whose competence in the history of science was more or less that of an amateur. At Wyrouboff's death, the professorship, the prestige of which had gradually declined, was abolished. It was re-established in 1920 and assigned to Pierre Boutroux; on his death, a few years later, it was again discontinued. Thereafter, the history of science disappeared from the curricula of the Collège de France.

The conclusion to be drawn from these misadventures is that it is always difficult to organize the teaching of a new discipline, and that in the particular case of the history of science the difficulties are increased because many people mistakenly think themselves qualified to define the character of the teaching and the capabilities to be shown by the professor selected.[1]

Better fortune attended the organizing of the teaching of the history of science in the United States of America, at Harvard University; here it was entrusted to George Sarton, who held the professorship from 1920 to 1950. The career of this distinguished historian of science is the only example that can be quoted of a career entirely devoted to the teaching of this new discipline; and his personal experience is thus of the highest value.[2]

Sarton had a varied audience composed primarily of science and medical students, with a few students of philosophy and history. After experimenting with several different approaches, he finally opted for a general course in the history of science, divided into four series of 35 lectures. These series, spread over two years, were devoted respectively to Ancient Times, the Middle Ages, the fifteenth, sixteenth and seventeenth centuries, and the eighteenth and nineteenth centuries, but, as each series was independent of the others, most students did not attend the whole four. Sarton considered this to be the minimum scope for a general course which would give

1. In order to appreciate the circumstances of these unhappy events, one should recall that the Collège de France is a learned institution independent of the University of Paris. No diplomas or degrees are awarded.
2. Cf. G. Sarton, 'Est-il possible d'enseigner l'histoire des sciences?', *Arch. Int. d'Hist. des Sci.*, t. 3, 1950, p. 3-38.

a correct idea of the wealth and diversity of science at the different periods and at the same time place the subject in its proper cultural context. These lectures have given many scientists and doctors a general grounding in history, and future philosophers and medievalists a grounding in science; they have also helped to train several competent historians of science who are now teaching in the United States of America and other countries. The establishment of a chair of the history of science at Harvard University has thus been a fruitful undertaking; and today, under Professor I. B. Cohen, it is still a world-famous centre of great influence and serves as an example to the other universities in the United States which are planning to introduce the history of science as a teaching subject.

After the founding of the professorship at Harvard University, where it was practically autonomous, several other centres for the history of science were established in the United States. The most important is probably that at Cornell University, under Professor H. Guerlac. Most of these centres are attached to the history departments of the universities. This arrangement has the advantage of simplifying administrative problems and ensuring regular recruitment of students; on the other hand, the professor is obliged to adapt his teaching to a single category of students and co-ordinate it more or less closely with the other subjects taught in the same department.

A comparable example is the chair of the history of philosophy and science which was founded at the Faculty of Letters of the University of Paris in 1932. This chair theoretically belongs to an Institute for the History of Science and Technology which is attached to the five faculties of the university. However, since the professor who directs the institute is necessarily a philosopher devoting part of his teaching time to general philosophy, the slant given to the studies destines them almost solely for philosophy students.

There are a few similar professorships in faculties of science elsewhere —for instance at the Université Libre de Bruxelles, where a basic course on the history of scientific thought is given for all science students.

The adoption of a general course on the history of science for a particular category of student (historians, philosophers or scientists) has the advantage of ensuring that the level and training of the professor's audience will be relatively homogeneous. Yet such teaching, with its restricted purpose, is only a partial answer to the problem. For this reason, some universities are considering establishing, in addition to this specialized instruction, new courses adapted to the needs of other categories of student. Although the intention is praiseworthy, this course of action might lead to a dispersal of effort that would be prejudicial to the cause of the history of science. If such courses are to be satisfactory, they must be accompanied by adjustments in the curricula and a general co-ordination of all branches of teaching which might otherwise become competitive. It is true that the

co-ordination of courses attended by students from different faculties is always a delicate operation as it may involve certain administrative or personal difficulties; but such artificial difficulties can always be overcome by clear-sighted and energetic administrators.

The solution we consider to be the most satisfactory is that advocated in a recent article[1] by Professor S. Toulmin, Professor of Philosophy at the University of Leeds—that is, the establishment in the main universities of separate departments for the history and philosophy of science, in which several professors, specializing in various aspects of the philosophy and history of science, would work together to organize both the basic courses and more advanced courses for the smaller numbers of students intending to do individual research in this field. Professor Toulmin gives two examples of such centres—one at the University of Melbourne and the other at the University of Wisconsin. He emphasizes the good results obtained from collaboration of historians, philosophers and scientists of different specialities. University College, London, has a similar department with several full-time lecturers and readers.[2] During the 1955-56 academic year, there were 59 regular students in this department—most of them reading for the M.Sc. degree, and the remainder for the Ph.D. There are also a number of smaller centres in the United Kindom, particularly at Oxford and Cambridge.

In other countries, such as the Union of Soviet Socialist Republics and the People's Republic of China, a special institute staffed by both professors and research workers is responsible for the general organization of teaching and research in the history of science. This system, which is possible only in countries where higher education is under the direct authority of the State, has the great advantage of making it possible to harmonize teaching in the different universities; in particular, it facilitates research by uniting documentation sources, improving collaboration between the different specialists and co-ordinating publication.

We should also note, before concluding this rapid survey, that many faculties of science and medicine and several scientific and technical colleges include the history of specific sciences or technologies in their curricula. Whatever the intrinsic value of these courses, most of which are due to the initiative of the professor of the subject in question, they are not sufficiently broad in scope to constitute real instruction in the general history of science. They are too technical to provide the broad culture and humanism inseparable from this subject, unless the professor's historical and philosophical flair is such that he can place the specific history he is

1. Stephen Toulmin, 'History and Philosophy of Science. A Pioneer Department', *Universities Quarterly*, vol. 10, August 1956, pp. 346-58.
2. This department is now directed by Professor D. McKie. Until last year the head of the department was Professor H. Dingle.

discussing within the wider context of the history of mankind and thus give it its full philosophical and methodological value.

The relatively large number of examples we have used to show the various ways in which the problems of teaching the history of science has been approached might lead one to think that such teaching is already fairly widespread. This, however, is not so. Some of the solutions described are obviously inadequate; and, in any case, only a small minority of universities have taken up the problem. The one positive aspect of the matter is that in many countries, e.g. the United States of America, the Netherlands and the Soviet Union, a sustained effort has already been made to encourage increased teaching of the general history of science, and that the benefits of this effort are gradually being felt. It is to be hoped that these examples will be followed by the still over-large number of countries which, lacking perspicacity or courage, have made no positive move in this direction.

OBSTACLES AND OPPORTUNITIES

The relatively slow progress of the teaching of the history of science is due not so much to a failure to recognize its importance as to the difficulties that are always involved in establishing a new teaching subject, particularly one so situated as to give rise rather easily to misunderstandings.

In such cases there are always a number of delicate problems to be dealt with: how to define the aims and methods of the subject with reference to the various categories of students for whom it is intended; how to situate it in the general curriculum; what degrees or diplomas should be awarded; what qualifications should be required of those who are to teach it; what relations should be established between it and seminars and research centres; what administrative organization is required, etc.

Because of its close connexion with science, philosophy and general history, the history of science occupies a very special position on the borderline of the human sciences, pure sciences and technology. This privileged position is undoubtedly one of the main reasons for its high cultural value. But it is also a source of numerous difficulties. Apart from the delicate problems it entails as regards the training of qualified teachers and the administrative organization of efficient teaching, it leaves room for serious misunderstandings as to the meaning and direction to be given to research and teaching in the history of science. These misunderstandings can have important consequences, since, in the absence of professional writers of the history of science, the administrators organizing the new branch of teaching will consult historians, philosophers and scientists, who, though very competent in their own fields, may have no knowledgde of, or may misunderstand, the problems peculiar to the history of science.

Historians and philosophers are well enough equipped to appreciate the humanistic value of this new discipline, but not to form a valid judgement concerning its content. There is a danger that, intimidated by the highly technical nature of scientific progress, they may deprive the history of science of its concrete content, retaining only general ideas which lose much of their value if they have no solid backing. While the philosopher is inclined to appreciate only the methodological aspect of science, the historian tends to place greater emphasis on the importance of technological progress and to reduce scientific evolution to its general cultural aspect. As for the scientists, their general attitude is certainly less favourable to the interests of the history of science. Many highly specialized research-workers have, in fact, lost all contact with the general evolution of science and, taking account only of their own narrow field of research, refuse to attach any value to teaching about the past. Others readily admit the cultural value of the history of science but devote their attention exclusively to the practical aspect of relatively recent developments and make the subject seem too technical, by isolating it from its human context. Others, again, underestimate the difficulties of historical research and are inclined to regard the patient and delicate work of the historian as merely a matter of drafting. George Sarton has also aptly remarked that the opposition of certain scientists to the history of science is 'an example of the fundamental conflict between creators and critics'—a conflict which can nearly always be traced back to misunderstandings on both sides.

This brief outline of the main misunderstandings caused by the history of science shows what are the principal obstacles that hinder its propagation in university circles. Fortunately, however, this is only one aspect of the situation, and the most elementary respect for truth and justice obliges us to recognize that there are many historians, philosophers and scientists who have a much more accurate idea of the aims and methods of the history of science. Without their disinterested support, the campaign for the extension of the teaching of this subject would have very little chance of success.

There is another, more practical difficulty—how to determine the administrative framework within which this teaching must be organized if it is to be really efficient. The examples mentioned above indicate the extreme variety of the solutions adopted. The simplest method is to organize the new branch of teaching within an already existing framework, by including it in the curricula of a particular faculty and by linking it fairly closely to one of that faculty's departments. This easy solution has the advantage of eliminating a number of administrative and material difficulties and of enabling a quick start to be made with the new discipline; but it has the serious drawback of ignoring the special position of the history of science, and of almost inevitably excluding some of the students who might profitably include it in their course of study.

A more ambitious solution, which would be more difficult to plan and to put into practice but which would yield much more fruitful results consists in the establishment of an independent department or institute of the history and philosophy of science. Such centres, of which we have already mentioned certain examples, should be devoted to both teaching and research; in addition to a course on the general history of science (with separate sections for students of literature and science), they would offer complementary courses with more limited aims, special courses on the history of particular disciplines, research seminars, and a documentation centre. At first sight, such a programme seems very ambitious, and it could in fact be implemented only gradually. To start with, in the absence of specially trained teachers, the teaching staff could be recruited from historians, philosophers and scientists who have proved their competence in this field. The teachers could—provisionally at least—remain attached to the staff to which they originally belonged, and devote only part of their time to the history of science. This provisional solution would be abandoned as soon as the institute itself had ensured the training of qualified teachers of the history of science. The possibility of implementing such a project successfully is shown by the fact that the history of art and the history of religions—both of which subjects were in a similar situation a few decades ago—soon established themselves in university syllabuses.

A final problem arises—how would the reforms envisaged affect the training of teachers? For secondary school teachers, it would be easy to rearrange competitive and other examination syllabuses so that they would cover the ground required. Science teachers should be given a thorough grounding in the history and philosophy of science in addition to more advanced study of the history of their own teaching subjects. The present position in this respect is far from satisfactory. It is most regrettable, for example, that teachers of mathematics in many countries receive no instruction in the history of mathematics, and may remain ignorant of such important figures as Euclid, Archimedes, Fermat, Newton and Leibnitz. A similar reform should be effected with regard to the training of history teachers; a special course is needed to give them a knowledge of scientific methods and of the main developments in the history of science and technology and these in turn should be given their due importance in general history courses.

The most difficult problem is that of the recruitment and training of teachers of the history of science and technology. As we have already suggested, these teachers should at first be recruited from among those historians, philosophers and scientists whose turn of mind and the original published work show that they possess the general scientific knowledge and the sense of philosophy and history to appreciate the methods, aims and content of this branch of cultural history. Inevitably their direct knowledge

of the various branches of this vast discipline will be much less detailed, but what is important is that they should have a thorough and first-hand knowledge of certain aspects of it and be prepared to make themselves familiar with it as a whole. It is essential that the various teachers in a particular centre should take a personal interest in different specialities; and it is even desirable that they should differ widely in training and background so as to introduce the greatest possible range of ability and outlook.

The problem of training students from the outset to teach this subject does not seem to have been dealt with satisfactorily yet in any country. The openings are still far too limited for such training to have been organized, and the only remarks we can make must be quite general in scope. The ideal teacher of the history of science and technology—capable of dealing, at all levels, with the various aspects of this vast discipline—would have to have more learning and more personal qualities than could be expected of any man. What can be expected, however, is that he should have a thorough scientific knowledge in at least one field and a good general scientific culture; he must also be familiar with the main stages in the development of the philosophy of science, and have some grounding in methodological questions; he should be experienced in the use of the historical method in his own original work, and be familiar with particular research problems in his chosen field of study. The most important requirement, however, is that the trend of his personal research should demonstrate a clear vocation and special aptitudes for this extremely specialized branch of instruction.

The object of these summary observations is simply to put forward a few arguments for the wider adoption of the teaching of the history of science and technology, and some suggestions as to how this might be done more expeditiously and effectively. No claim is made to offer a solution to all difficulties, since each individual case has its particular circumstances and problems which it would be useless to consider in the abstract.

CURRENT PROBLEMS AND RECENT NEWS

Scientific Problems and the 1959-65 Seven-Year Plan in the U.S.S.R.

by

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In the Soviet Union's progress towards Communism, a prominent part is being played by the discoveries and attainments of Soviet science and their application in production. Science has become a mighty transforming force in the hands of millions of builders of the new social structure. The progress of science is at the root of the development of all planned socialist economy. Conversely, the planned and unified development of complex scientific research is becoming a characteristic of Soviet science. An examination of the basic scientific research plan for the present seven-year period will make this quite clear.

The selection of the most important fields of scientific study is based on an analysis of the present stage of scientific development in the Union of Soviet Socialist Republics and in other countries. By means of this analysis, the Soviet Government and Soviet scientific organizations have been able to identify very rapidly the branches of science which are likely to provide us, in the near future, with broader and deeper knowledge of nature and mankind. On the other hand, the development of selected fields of study should have a marked effect on the technical advances made in industry and transport, and on the growth of agricultural production.

Soviet scientists have been successful in discerning the most important sections of the general scientific field on which our attention, energies and resources will have to be concentrated in the future. The planning of scientific research is, broadly speaking, directed by the State. The lines of future scientific development are determined in accordance with the seven-year plan, and the importance of each branch of science in the development of the nation's economy is defined.

In the natural sciences, attention at present centres on the physical sciences. Their development largely determines progress in the most important departments of modern technology. There are many facts which will not fit into the framework of existing theories, and this makes it essential for new steps to be taken in the development of theoretical physics and the formulation of general theory.

The solution of the numerous problems related to the peaceful use of atomic energy depends on knowledge of the structure of the nucleus and the nature of intra-nuclear reactions. For this reason the basic task of nuclear physicists is to carry out further study of these questions. The objective of scientists will be to formulate a general theory of the structure of the nucleus, and a theory of nuclear reactions. Research into cosmic rays must be carried further. Research into new forms of nuclear energy—and particularly, controllable thermo-nuclear reactions—is of the greatest importance.

Further research in the field of neutron physics should lead to the perfection of atomic electric power stations, and to a reduction in the cost of power. We also anticipate significant developments in research in astronomy, solid state physics, low-temperature physics, radio-spectroscopy, etc.

One of the oldest of the sciences, astronomy, gained new life with the brilliantly successful release of the Soviet cosmic rocket—the first in the world—which became an artificial planet in the solar system. Research into the nature of the physical processes taking place in cosmic space then became the centre of interest for astronomers. Important developments may be expected in the technique of semi-conductors, which has become the basis for fundamental changes in many departments of radio-technology and computation techniques, and the associated sections of modern industry.

The accelerated development of science and technology and the transition to complex automation in production call for the invention of new and more productive specialized calculating and controlling machines, and the solution of fresh problems in computation techniques, the logic of mathematics, the theory of planning, etc. In the present seven-year period, calculating machines should be very widely used, not only in scientific work but also for planning, for the direction of production, and for statistical and computation work. The installation of a wide network of computation centres will make possible the prompt issue and processing of information in the Councils of National Economy, in centres in the republics and regions, and throughout the Soviet Union.

With the launching of the first cosmic rocket, which provided further evidence of the achievements of Soviet science and technology, the way was opened for interplanetary communication. The flight of this rocket beyond the atmosphere of the Earth reveals the tremendous possibilities that may result from a study of the currents of corpuscular radiation of the

Sun and of hard photons in cosmic rays beyond the sphere of active influence of the Earth's magnetic field. For the first time, it has become possible to study the magnetic field of the Moon and its radio-activity, which is of great importance in discovering the origin of the magnetic field of the Earth and other heavenly bodies. Now Soviet scientists and technicians are faced with such tremendous problems as those of enabling man to fly beyond the atmosphere and return to the Earth, sending airborne craft to other planets for research purposes, and establishing permanently operating scientific research laboratories in inter-planetary space to study physical processes which take place far beyond the Earth.

The various sectors of modern technology require the production of new materials with specific properties. This can only be done if we can completely master solid state physics, the chemistry and physics of high molecular compounds, organic synthesis, physical chemistry and crystallophysics.

Initially, Soviet chemists will concentrate on working out the principles and methods of producing artificial and synthetic materials, rubber, plastics and fibres with given structure and properties; searching for a method of obtaining high molecular compounds, including durable heat-resistant rubber polymers; producing chemical fibres which are durable and elastic and at the same time resistant to chemicals, heat and light, and which have the same properties as wool; and studying the structure and mechanism of the formation of biologically active polymers which play a part in the activity of the living organism.

In oil chemistry, there will be research into the many types of thermal and catalytic transformations of the hydro-carbons of oil, and the establishment of the most effective and economic methods of processing oil-gases from oilfields and cracking plants.

In the chemistry of element-organic compounds, Soviet scientists will concentrate on working out metallo-organic catalysts of a basic organic synthesis, catalysts of polymerization and new industrial synthetic processes; finding new monomers and new polymeric materials, especially those which are resistant to heat and to chemicals; and producing lubricating oils and other materials resistant to chemicals and to heat.

Extensive research will be carried out in the Soviet Union in organic chemistry and the chemistry of natural substances. Special attention will be paid to methods of isolating and ascertaining the structure and properties of the most important proteins.

Another important field of work will be the search for new antibiotics to counter dangerous infections, virus diseases and malignant tumours. Research will also be carried out on the structural analogues of substances related to antibiotics.

Every year, greater use is being made of atomic energy for peaceful purposes, and this creates a need for a real effort in research into the radio-

chemistry of transuranic and fragmentation elements. New and cheaper isotopes must be obtained, together with sources of radiation which will be extensively used in all departments of human activity. Industrial problems of great importance will also be solved by research in radiation chemistry.

In the U.S.S.R. there will be two basic lines of research in the use of mineral resources to meet the needs of the national economy. First, there will be a number of scientific surveys to increase the efficiency of geological research and prospecting, with the specific aim of finding new deposits and extending the supply of useful minerals discovered in the earth; and secondly, we shall examine a number of scientific problems bearing on the general improvement of scientific standards and economic efficiency in the use of our mineral resources. Geologists will pay particular attention to the study of the regularity of the formation and location of useful minerals within the territory of the U.S.S.R., particularly in the east. This study will also be used as a scientific basis for the division of the country into regions for geological investigation. Research carried out by geologists will make it possible to produce metallogenic maps of the most promising regions of the country—particularly parts of Siberia—and prognostic maps of deposits of oil from which gas can be produced.

The results obtained in research in biological science are put to practical use in many important departments of life. The development of this science is essential as a theoretical basis for the improvement of plant-growing and cattle-raising, and for the progress of medical science and of industries which use raw materials of biological origin. Biologists also have a great deal of work to do in the development of agriculture and in improving the productivity of the soil and of livestock.

Great importance attaches to research into the origin and nature of life, knowledge of the physico-chemical bases of the elementary life processes, research into cells and the metabolism of cells and living organisms, the elucidation of the chemical composition and physical structure of proteins, nucleic acids and lipids, knowledge of the basic principles of heredity and its variability, the biochemical and physiological bases of the vital activity of micro-organisms, the chemistry and physico-chemistry of virus particles, the chemistry of photosynthesis, problems related to the feeding, growth and development of micro-organisms, plants and animals, and other problems.

The importance of the biological sciences is greatly increased if creative use is made, in biology, of the findings of physics and chemistry. Branches of science such as biochemistry, agricultural chemistry, biophysics, cytology, microbiology, genetics and virology will have great significance. Success in these fields depends on the extensive use of the latest physical and chemical research methods.

Soviet biologists will pay particular attention to the development of

Michurin's theories and Pavlov's teachings on the activity of the higher nervous system, and to the establishment of a closer relationship between the biological sciences and agriculture, medicine and industry.

The main lines of scientific research to be pursued in technology are determined in accordance with the principal tasks of technical progress as revealed by the scheduled figures of the seven-year plan. In this connexion, particular attention will be paid to research into the possibility of making definite qualitative improvements in the effective use of working tools, raw materials, fuel and electric energy. Research will also be conducted into ways of increasing the productivity of labour, reducing costs and improving the quality of goods produced. At the same time, cultural standards will be raised and working conditions will be made safer.

The main factors in ensuring continued technical progress, as N. S. Kruschev says in his report, are the complex mechanization and automation of production. It is the task of Soviet scientists to do all that is needed to bring about complex mechanization and the change from the automation of separate units to the complex automation of the whole workshop and of technological process and industrial undertakings; a special branch of their work will concern the establishment of experimental factories, completely automated, for purposes of demonstration. Related to this problem are other questions of great scientific importance, connected with the automation of the process of production to secure the highest possible output, the working out of self-determinative systems, knowledge of the regularity of technological processes and the mathematical expression of those laws. The transition to complex automation will necessitate considerable changes in present industrial technology; and, in many cases, essentially new processes will have to be worked out and new equipment and technical means of automatic control installed. In the process of production, increasing importance will be assumed by fully automated machinery, machine tools and units which operate on a predetermined schedule. The projected development of automation will mean that greater importance will be attached to expanding research in a comparatively new branch of science—cybernetics, with a study of the processes and principles of control and the methods of constructing control machines and systems.

Growing importance in the technical process is attached to radio-electronics—used in calculation, mechanics, television and communication. It is being increasingly employed in a great variety of branches of the national economy and everyday life. Much more research is needed to discover better methods of transmitting communications and gaining control of radio-waves of all ranges.

Soviet scientists are faced with other tasks, related to laying a scientific basis for the use of our sources of energy, the construction of thermal electric power stations, the installation of long-range electro-transmission and

the establishment of a single energy system for the Soviet Union. In connexion with the construction of powerful atomic electric power stations, it is intended to carry out research on a number of problems of heat engineering—particularly the selection of heat conductors—and on thermo-motors driven by nuclear energy and fissile materials.

Other important research envisaged concerns the multiple uses of fuel with a view to the maximum exploitation of fuel materials, the reduction of specific costs, and the wider use of chemical sources of raw materials. There is work to be done on the methods of the gas-chemical use of fuel, particularly the method of obtaining high-calorie gas and various chemical products, raw materials, scattered elements and metals.

In the social sciences, the main factors in determining the principal fields of research are: consideration, in broad outline, of the ideological tasks set by the Communist Party of the U.S.S.R.; the necessity for greater experience in socialist construction and the handling of problems related to the gradual transition to Communism; the necessity for further development of Marxist-Leninist theory; and the need to combat unscientific reactionary theories and the various manifestations of revisionist thinking.

The science of economics is gaining greater significance in present-day conditions. It must be closely linked with the planning of the national economy and with every facet of Communist construction. Certain problems related to this science are becoming more and more important—such problems, for example, as analysing the development of the national economy, finding more effective ways of achieving technical progress, increasing the productivity of the people's work, rationalizing the application of capital investments, making a technical and economic analysis of the latest scientific achievements, providing for specialization and co-operation in industry, etc.

These basic lines of development of Soviet science are of crucial importance for all future scientific research. If we succeed in solving the problems with which we are faced, we shall be able to make great advances in the discovery of the laws of natural and social development and to make a number of suggestions in relation to the national economy, directed towards a rapid increase in the productivity of the people's labour and enabling us to exploit to the full our very rich natural resources and to make still greater progress in developing all the productive forces of our country.

The international conference on scientific information

Washington, D.C., 16-21 November 1958

by

PAUL BOQUET

Dr. Boquet is Head of Laboratory at the Institut Pasteur, of which he has been a member since 1934. He specializes in microbic toxins and venoms. About one hundred of his notes and papers on these subjects have appeared, and in 1947 he published a book on serpent venoms and antidotes. In 1948, he was awarded an International Fellowship of the Commonwealth Foundation and spent a year working in several large universities in the United States of America. He has been awarded several prizes for his writings.

The London conference of documentation specialists of the British Commonwealth, held in 1948 under the sponsorship of the Royal Society, and the conference convened in Paris by Unesco the following year, to study the problem of preparing, classifying and disseminating abstracts, were instrumental in drawing the attention of the scientific public to the problem of documentation.

In response to the wishes of the Advisory Committee on Documentation and Terminology, the American Documents Institute proposed, in 1955, that an international conference of technicians and users of information should be organized. Unesco and two large institutions in the United States of America, the National Science Foundation and the National Academy of Sciences, combined their efforts with those of the American Documents Institute, and an executive committee under the chairmanship of Dr. A. Thomson was set up in 1956.

After the death of Dr. Thomson, whose ability and devotion to his work were appreciated by all those associated with him, this committee was modified, and in 1958 it finally consisted of the following seven members: Messrs. W. W. Atwood, chairman, member of the National Academy of Sciences, B. W. Adkinson, of the National Science Foundation, M. O. Lee, of the American Physiological Society, C. I. Campbell, of the Rockefeller Institute, H. J. Dubester, of the Library of Congress, J. C. Green, of the Department of Commerce, and Mrs. McC. Sheppard, secretary.

This committee decided that the conference would be held in Washington and would be divided up into seven sections to deal with the following topics:

1. Literature and reference needs of scientists.

2. The function and effectiveness of abstracting and indexing services.
3. Effectiveness of monographs, compendia, and specialized centres. Present trends and new and proposed techniques and types of services.
4. Organization of information for storage and search: comparative characteristics of existing systems.
5. Organization of information for storage and retrospective search: intellectual problems and equipment considerations in the design of new systems.
6. Organization of information for storage and retrospective search: possibility for a general theory.
7. Responsibilities of governments, professional societies, universities, and industry for improved information services and research.

The conference was held at the Mayflower Hotel, in a cordial atmosphere, and lasted from 16 to 21 November 1958.

There were 1,000 participants, 164 of whom were officially invited authors, rapporteurs and heads of sections, and the remaining 836 observers. Only those officially invited were authorized to speak; they included 102 participants from the United States of America, 33 from the United Kingdom and 8 from France, and 21 delegates (8 from Western Europe, 6 from Eastern Europe, 2 from India, and 1 each from Argentina, Canada, Israel, Japan, and the Union of South Africa).

The 75 papers selected[1] had been printed in a volume of 1,420 pages, copies of which were distributed before the opening of the conference. The general rule for meetings was to ask authors to refrain from presenting the contents of their reports orally; rapporteurs were assigned the task of analysing the essential material in these documents, and drawing conclusions. The rapporteurs formed the bureau of each section, and the section chairmen presided over the meetings at which their subjects were discussed. The chairmen were P. M. Morse, of the Massachusetts Institute of Technology (first section); E. Hutchisson, director of the American Institute of Physics (second section); A. King, director of the Organization for European Economic Co-operation (third section); E. de Grolier, director of the Centre Français d'Echanges et de Documentation Technique (fourth section); G. W. King, member of the governing body of the I.B.M. Research Centre (fifth section); W. Tuckey, professor of mathematics at Princeton University (sixth section); and W. Clapp, president of the Council of Library Resources (seventh section).

For practical reasons, the language spoken during the conference was English.

A summary of the work done in each section is given below.

1. Three of them (two by B. C. Vickery, and the third by E. Törnudd) were summaries of work done in collaboration with Unesco.

First section. Information methods in the sciences must be based on the results of surveys to ascertain the needs of the scientific public; however, there should first be some understanding about what kind of people are to use this information. According to J. D. Bernal, users are not generally capable of judging the worth of documentary techniques made available to them. They know what will be of use to them when they apply to a documentation service, but they are unaware of the extent to which the procedure used to inform them can be improved. As they are at present conducted, surveys on the way in which the scientific public gets its information are only of limited value. What users obtain from very inadequate documentation services is shown, but there is no indication of what might be provided by such services if they were better adapted to their role.

H. Hogg and J. Roland Smith, who have subjected the documentation sources utilized by scientists to special study, questioned 157 scientists in five laboratories supervised by the United Kingdom Atomic Energy Authority. They discovered that most of these scientists obtained information which would be useful in their work through conversations with their colleagues and with specialists in the same disciplines.

Throughout the 14-day period of the survey, 40 per cent of the persons observed by these two English experts did not look for a single bibliographical reference. Among those who engaged in bibliographical research, only 4 per cent made use of reviews which published abstracts of scientific articles. Identical conclusions were recorded by B. Glass, H. Norwood and C. Scott. Lastly, D. Urquhart drew attention to the fact that three-quarters of the periodicals of the Science Museum Library in London were practically never used.

However, a similar survey in Denmark and Finland led E. Törnudd to a different view. Most of the laboratory workers questioned obtained their information from scientific literature, and each of them regularly consulted some fifteen reviews.

These examples show that the results of research which may profitably be employed by information specialists in the country where the research was conducted are not necessarily usable in another country.

Second section. Methods of analysing and classifying documents were subjected to criticism which, generally, seems justified.

Experts whose task it is to index articles are no longer, despite all their efforts, able to process the great mass of documents now being published. E. Brodman and S. I. Taine say that, in the course of their research, they listed twice as many titles of medical periodicals as are found in the *Current List of Medical Literature,* the largest medical index in the world.

According to D. I. Welt, the indexes of a large number of reviews devoted to the publication of abstracts are prepared, not on the basis of the

contents of the original articles, but on that of the abstracts. Misunderstandings and omissions sometimes result, and handicap the users of the indexes.

Abstracting reviews themselves condense only a portion of scientific literature. This drawback is due to various factors: some periodicals have a very limited circulation, abstracting done by many institutions in different countries is not co-ordinated, and there are language barriers. Furthermore, the time it takes to note the contents of periodicals and to classify and analyse scientific documents often causes excessive delays in the publication of abstracts. Lastly, the form to be given to these abstracts is a matter of some disagreement between the partisans of very brief, 'indicative' abstracts, and those of longer, 'informative' abstracts. However, most experts agree that the preparation of abstracts of scientific articles must be entrusted to specialists and not to the authors of the articles. With a view to rationalizing abstracting methods and promoting exchanges between abstracting review of different countries, several persons have set forth arguments of unquestionable value in favour of the publication of authors' summaries. Thus, S. Herner points out that summaries published as 'conclusions' in original articles are often utilized by those who prepare abstracts of those articles. Likewise, G. A. Boutry, secretary of the International Council of Scientific Unions, recalled that his organization recommends the use of authors' summaries in the preparation of several bulletins of abstracts concerning physics and chemistry. The results of the international collaboration initiated by ICSU in the exchange of abstracts—the history and development of which were described by G. A. Boutry in the seventh section of the conference—were carefully studied by B. M. Crowther. Limited material resources available, the increasing number of Russian-language publications, difficulties in the classification of abstracts, and even technical obstacles sometimes met with, are all problems which the competent services of ICSU are endeavouring to overcome.

Since there are still only limited exchanges of abstracts between reviews of different countries, the question arises of the means used to improve the quality of these reviews. In this connexion, the statement by Professor Mikhailov, director of the Institute for Scientific and Technical Information of the U.S.S.R. Academy of Sciences, is of real value.

The U.S.S.R. Institute for Information was founded in 1953 in order to keep Soviet scientists abreast of the results of research carried out on the five continents.

The institute publishes 13 journals devoted to abstracts. Each journal deals with publications concerning a particular scientific discipline. In 1957, these journals published 400,000 items based on the contents of Soviet periodicals and of 12,250 reviews sent to Moscow by 88 different countries. The institute issues an index of abstracts. It provides Russian trans-

lations of foreign articles, and some of its services perform bibliographical work. It exchanges publications with 580 bodies in 46 countries. A research team attached to the institute is engaged in research on the mechanization of information work. Despite their size, Soviet reviews of abstracts are low in price. We were astonished to learn that the 24 yearly issues of the review on the biological sciences cost 700 roubles in the U.S.S.R. In a comparative study of the information sources represented by abstracting reviews, Gaudenzi observes that the ASM *Review of Metallurgical Abstracts,* the most comprehensive review for metallurgy in the Western world, presents 8,000 abstracts annually, whereas the corresponding review in the Soviet Union publishes more than 14,000. These figures would appear to support Mikhailov's view that only national institutions possess adequate means for collecting the largest amount of information and disseminating it effectively.

Third section. With regard to the operation of scientific information centres, Professor Wyart's report recalled the successive achievements of the organizers of the French centre during the past twenty years. Apart from the 'indicative' bulletin it publishes, this documentation centre does bibliographical work and translates articles published in foreign languages. Every month, it distributes a microfilm bringing to the attention of the public articles assembled by more than 300 scientific and technical periodicals. It should, however, be noted that the 'indicative' bulletin has no index.

During the meeting devoted to the third section, I. Leitch laid particular stress on the usefulness of '*synthetic*' reviews and their role in the dissemination of information. These reviews, some of which are followed by extensive bibliographies, meet the need voiced by many scientists for regular critical accounts of work done in their own or neighbouring fields.

Fourth section. The fourth section was concerned with the comparative study of methods of storing and searching for information. There are innumerable difficulties in a task of this kind and the problems of storing and searching for information vary according to the origin, destination and number of the documents involved. The subjects dealt with in this section served as introductory material for the discussions which followed in the fifth and sixth sections.

C. Cleverdon described the conditions under which an experiment was undertaken in the United Kingdom to compare the practical value of the following different methods used to index 18,000 documents on flying techniques: the universal decimal classification, an alphabetical classification by subjects, an analysis based on the principle of faceted classification, a research procedure used by Cleverdon and based on the method known in the United States of America as 'Uniterm'.

The problems relating to the first three techniques used by Cleverdon

will not be considered here since they were discussed in the following section. Attention should, however, be drawn to the 'Uniterm' method, which is founded on a rational system of co-ordinates. Superimposed perforated cards, called 'Peek-a-boo' cards in the United States, are prepared in accordance with the same principle.[1] E. Miller, D. Ballard, J. Kingston and M. Taube, on the one hand, and C. J. Wessel and W. M. Bejuki, followed by R. C. Wright and C. W. J. Wilson, on the other hand, described the results of their investigations into the use of superimposed perforated cards and showed how efficiently they could be used in practice.

Discussion on the substitution of machines for the human hand in documentation work followed accounts given by A. Opler and N. Baird, by W. H. Waldo and by W. de Backer of several experiments made with electronic ordinators. One of these experiments was to compare the results of documents search by an I.B.M. 704 machine under various conditions. Two similar programmes drawn up by two chemists using different systems of classification were presented to this machine in order to determine which system allowed of quicker selection. The second experiment, carried out by the Monsanto Company, was to feed to the memory of the I.B.M. 702 machine the results of daily research on new substances, and later to extract from its memory whatever information was essential for new research on those substances. A code of chemical formulae was drawn up first.

Fifth and sixth sections. Most of the discussion was devoted to theoretical studies on information.

The oldest systems of classification, known as systematic or analytical classification, consist of extracting from a document the terms which define it and inserting them in a linear system with a variable number of ramifications. The order in which these terms are distributed is unalterable.

The rigidity of such classification systems now no longer meets the needs of scientific disciplines. The characteristics determining the position of a document in a linear system are sometimes selected arbitrarily, and certain characteristics that appear to be of lesser importance can later take on major significance. Furthermore, the search for a document will be fruitless unless the terms selected to guide the search correspond to those of the classification system. The trend in the past few years has been to replace these methods with systems of classification in several dimensions, in which an item of information is characterized by a group of mobile descriptive elements. There is no limit to the number of such elements; and the more numerous they are, the more precise documentary research becomes. Each

1. Superimposed perforated cards appear to have been discovered independently by Taylor in the United States of America in 1915, Liber and Borgeaud in France eight years later, and then by Batten in the United Kingdom seven years ago; but G. Cordonnier is responsible for the most extensive improvements in the use of such cards.

descriptive element expresses an idea previously defined by a semantic and conceptual analysis of the information available. Such analysis can be carried to its extreme limit; 'thus . . . one must needs arrive at primitive words which can no longer be defined, and at principles so clear that none which are clearer can be found to prove them' (Pascal).

Drawing both on the constructive system which has just been briefly described, and on the work of the Indian scientist Ranganathan, the English classification specialists B. C. Vickery and J. D. Foskett advocated use of the procedure known as 'faceted classification' so called because of the relationships existing between the categories into which the terms used to characterize an item of information are distributed. However, the idea of 'categories' is today tending to disappear; it is possible to share V. Sherenin's belief that, in the near future, procedures for the selection of information will be based on the use of a new language created by documentary research.

A study on archaeological documentation, presented by J. C. Gardin, attracted special attention. It concerned a method of analysing forms and figures which could then be defined, catalogued and selected. The method consists of breaking up the forms or figures into elements comparable to the 'morphemes' of language, and of determining the ways in which such elements are related. The distinctive characteristics of a figure or form are then expressed by a series of symbols specifying the nature of its component elements and their relationships to one another. With this process an international code can be established. The method described by Gardin has the advantage of substituting combinations of definite terms for complex units from which it would be difficult to extract information directly. The method, being objective and analytical, will doubtless be extended to many types of graphic representation and even to all kinds of searching for information.

For several years now, a considerable amount of study has been done on machines designed to explore the documentary universe and on the codes constituting the language of such machines. These machines, which are designed according to the principle of analytical systems in several dimensions can be divided into two main categories.

Those in the first category record each document on a support forming part of the artificial memory and then, on the same support, define its distinctive characteristics. The search for a document consists in going through all the available elements of the memory in order to find the one whose characteristics were fed to the machine. The length of the searching-time depends on the number of comparisons which the machine must make.

Three types of apparatus have been proposed:

1. Mechanical selectors of perforated cards—of limited use because of their great inertia.

2. Electronic ordinators, which have been experimented with for several years in the United States of America, France and the Soviet Union.
3. Selectors of documents recorded on small-size photographic film. This types includes Samain's 'Filmorex' and the Kodak Company's 'Minicard'.

A logical study of the operations of storing and searching for information leads one to think that the essential guiding principles for systems designed to ensure these operations are by no means those which enable ordinators to analyse the data for a problem, to add, to subtract or to multiply. Like H. Coblans, we must admit that machines will do a rational job of selecting information only in so far as our theoretical knowledge of the classification problem advances.

Recent research has made it possible to replace the processes described above by a more rapid technique, in which all information of a common character is collected on the same support. The search for the document is then merely a matter of exploring the memory in the field defined by the characteristics selected. It is in this manner that the machines in the second category operate. Three new types of machine, corresponding to the three types in the first group, have now been developed:

1. The I.B.M. 9,900 selector of perforated cards.
2. The Ramac electronic informer, whereby 25,000 documents can be recorded on 50 magnetic discs.
3. Lastly, several kinds of photo-electric apparatus using the 'Peek-a-boo' perforated cards, which are now being studied in the United States of America and France.

Those attending the conference were able to see the 9,900 and Ramac machines during a visit to the I.B.M. establishments, and at an exhibition in the Mayflower Hotel.

Attempts have recently been made to use electronic machines to solve such complex problems as the preparation of abstracts of scientific articles and the translation of these articles from one language into another.

During our visit to the I.B.M. plant, we watched the analysis of a text by the 704 machine. The process was ingenious, but the method of analysis used in this case took no account of several factors which distorted the statistical results obtained by the machine: for example, the use of synonyms to avoid repeating the same word. The apparatus can, however, be improved, and it opens up a new field for investigation by linguists.

According to V. H. Yngve, the definition of symbols whereby an index can be prepared in order to simplify the search for information and to translate one language into another creates similar problems, which are eminently worth studying. Z. Harris and J. Whatmough reported the results of their research on this subject, and G. P. Meredith described a technique of conceptual analysis of texts based on the Cartesian principle of the translation of an algebraic function into a geometric figure. R. A. Fairthorne

and C. M. Moores presented a mathematical theory of codes used in the search for documents.

The analysis of language structure has led specialists to experiment with the mechanical translation of texts from one language into another. The original conception of a machine acting as a mere automatic dictionary is gradually giving way to the idea of a robot capable of analysing the syntactical relationships between the terms in a text, the grammatical forms of words, and their semantic content. A. G. Ottinger, W. Foust, V. Giuliano, K. Magassy and L. Matejka explained the methods used in preparing the Harvard automatic dictionary planned for the translation of Russian into English. Thereafter, M. Masterman, R. M. Needham and K. Spark Jones, of the Cambridge Language Research Unit, recommended the use of an 'interlingua'. This 'interlingua' is actually not a language, but a system based on the use of a thesaurus.

Seventh section. What suggestions can be made for improving the operation of information services, and what responsibilities must be assumed by governments, learned societies, universities and industries in order to effect a large-scale dissemination of information?

Taking the view that sources of scientific information constitute a national asset, Hazel Mews advocated the establishment, under State responsibility, of a committee to deal with all documentation problems, and the creation of a national scientific and technical information centre. M. O. Lee suggested the founding of a national information centre for biology in the United States. G. S. Bonn stressed the need for training specialists in the disciplines relating to documentation. After comparing teaching methods in 24 countries, he proposed certain reforms, including a broader international exchange of specialists and the establishment of an international teaching institution. Finally, P. Boquet and W. Chamberlain presented two projects for the creation of an international documentation centre. Chamberlain had in mind a large-scale institution which would enable information to be disseminated more effectively and would reduce present expenditure for this purpose. He then gave a detailed analysis of such an institution's budget. Boquet based his idea on the fact that the work of the various information services must be co-ordinated, and close co-operation between all of them ensured.

C. E. Sunderlin examined the difficulties involved in organizing an international information centre, and expressed disapproval of these projects. M. Kotani, however, suggested that co-operation could be established in the limited field of one scientific discipline, by means of exchanges of information between specialized centres of different countries; the largest of these centres would be asked to assume the responsibilities of an international institution. Kotani's idea is contained in Boquet's project, which

envisages the building of an international information centre by successive stages. So flexible a programme would make it possible for existing documentation services to remain autonomous while adapting themselves to the requirements of circumstances.

By holding a conference in Washington on scientific information, United States documentation specialists had intended, not to define a policy, but merely to open a general discussion on the results of the most recent research effected in the field of scientific information. These results showed that two large countries, the United States of America and the Soviet Union, had for several years paid close attention to the role of institutions whose aim was to inform scientists and technicians. The National Institute described by Professor Mikhailov was established in the U.S.S.R. for this purpose; and this institute, which was widely discussed by the delegates, has great material resources at its disposal.

In the United States of America, whose economy is based on free competition, it would be difficult to imagine a documentation centre comparable to that of the U.S.S.R. The work of providing information is shared in the United States of America by many private bodies, various foundations, and government institutions. The many efforts of these bodies have had the general result of increasing the number of studies undertaken in the United States with a view to ensuring better dissemination of scientific information. Some of these studies will be valuable, and those responsible for the United States economy are aware of the fact. However, a scattering of forces does not help research to develop systematically. Following a natural law, documentary bodies tend to coalesce into groups, and 14 of them have already constituted a federation.

Co-operation between all countries in the documentation field, through an international documentation centre which would serve as a real link among documentary bodies, is doubtless hard to imagine today; but the idea of such co-operation, based on the results of experience acquired in other fields, will gain ground as information techniques improve.

Although the review of the reports presented at the last meeting of the conference cannot be regarded as incorporating any conclusion, it nevertheless shows that further efforts must be made in every country to establish a research programme for defining the methods of information best adapted to the requirements of scientists.

In conclusion, the author would like to reiterate the hope, expressed in Washington by Dr. Urquhart and Professor Bernal, that the Academies of Sciences of all countries will collaborate in order to continue the work of the first International Conference on Scientific Information.

World-wide appeal for Brazilian science library recently destroyed by fire

Unesco and the International Atomic Energy Agency have begun an emergency campaign to assist the Centro Brasileiro de Pesquisas Físicas (Brazilian Centre of Physics Research) to re-build its library which was completely destroyed in a recent fire.

At the June session of the Unesco Executive Board, Professor Paulo de Berrêdo Carneiro, Brazilian member of the Board, announced that the library's entire collection of vital scientific works had been lost in the fire. The library's documentation in the fields of nuclear physics and higher mathematics was unique in Latin America.

The Executive Board immediately responded with a series of recommendations for combined international assistance, requesting Unesco, the International Atomic Energy Agency and the United Nations Technical Assistance Board to assist in the efforts to re-build this vital centre of scientific progress and intellectual collaboration.

Following the Executive Board's proposals, the library was at once placed on Unesco's list of Gift Coupon projects, and a special appeal is now being launched in all Gift Coupon donor countries.

The Board also urged that the appeal be publicized among universities, libraries, technical institutes and non-governmental organizations, as well as in all the Unesco Member States.

Any institution or organization wishing to join this international effort to help re-establish the library so that it can resume its important place in the scientific advancement of the South American continent should communicate directly with the

CENTRO BRASILEIRO DE PESQUISAS FISICAS
71 Avenida Venceslau Bras, Rio de Janeiro, Brazil

Offers of equipment, duplicate volumes, micro-films, abstracts and other documentation should also made directly to the Centre. Cash gifts may be transferred most conveniently in the form of Unesco Gift Coupons, about which complete information may be obtained by writing to Unesco's Public Liaison Division, Place de Fontenoy, Paris-7e, France.